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—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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THE ANIMAL AS A PRIME MOVER.

BY R. H. THURSTON.

PART I. THE HUMAN ANIMAL AS A VITAL PRIME MOVER AND A THOUGHT-MACHINE; THE ENERGETICS OF THE VITAL MACHINE; ITS TRANSFORMATIONS.

The Vital Engine, the body of every vertebrate animal—from the human ruler of all, down to the lowest organism having a cartilaginous frame—is to-day well recognized, as, in the engineer's classification, a "prime motor," in which the latent forces and energies of a combustible "food," of a fuel, as many suppose it, are evolved, transferred and transformed to perform the work of the organism itself, to supply heat to keep it at the temperature necessary for the efficient operation of the machine, and for the performance of external work. The value of the machine as a prime mover is dependent upon the relation between this external work, so far as it can be applied to useful purposes as labor, and the

costs of its production in fuel or energy supply, and in wear and tear and replacement, precisely as with any other machine of the class, whether the source of power be chemical, thermal, electrical or vital.

The work of the machine is, however, a very different quality and is vastly different in quantity, useful work being compared with supplied energy and incidental expenditures from that of any other known motor. In the water-wheels and windmills, the office of the motor is simply that of transfer of energy of flowing currents of fluid, of water or of air, and, without transformation, to mechanism suitable for giving it useful application. The heat engines develop energy previously "latent," potential, as the modern nomenclature would call it, into the kinetic form of thermal motion, and by transformation, so far as may be practicable, into the dynamic form, make it available for work. Electro-dynamic machinery similarly makes available by transformation the energy of the electric current; and none of these machines has any other function than that of making useful some one energy previously stored by the operations of Nature in such form as to be readily applied to his purposes by the hand of man.

The vital machine, on the other hand, has purposes and performs offices of essentially different kinds. It must not only transform the latent energies of the supplies received by it into useful external work, but all its work being directed toward the sustenance and preservation of the contained soul, as its principal and always essential purpose, all its operations being automatic or self-directed, all its powers of transformation of energy are demanded for the production, by transformation, presumably, of (1) the vital forces and energies; (2) the physical energies demanded in constructing, rebuilding and operating the animal frame; (3) the external work required to furnish the body supplies, to protect it from decay or injury, and to minister to the physical wants and ethical requirements of the personality of which it is at once the home and the vehicle.

This curious prime mover is thus an apparatus which,

from familiar sources of energy, transfers and transforms, for its own purposes and applications, a variety of energies, performing a variety of work in various realms. The nature and composition of the sources of latent energy, always chemical compounds capable of oxidation, are well known; the character and method of many of the internal, as well as of the external expenditures of energy, are equally well understood; but there are a variety and considerable number of internal operations, involving transformations of energy, the nature and method of which are entirely beyond observation by any process of experimentation yet devised.

"Food" is taken into the body, enters into solution with the peptic fluids, elaborated from previously supplied nutriment, is absorbed into the circulation, and disappears from our sight and reach; heat, carbon-dioxide, vapor of water, various salts, and a considerable proportion of unutilized nutriment, are rejected from the system, and work is performed as the product of transformed energies and in large amount, both within the machine and upon external bodies. A chain of energy transformations is in continuous operation, of which we see the two ends, so far as the vital machine is concerned, but of which we only get occasional glimpses between the extremities, and some of the links of which are, as yet, undiscovered and unknown. It is certain that the series of changes, material and kinetic, involves familiar methods of transformation, and it is hardly less certain that singular and probably wonderful and unknown processes of energy development and transformation are concealed within this miracle among machines.

Possibly a study of the present state of scientific research, relative to this machine, may give at least some idea of the importance and complexity of the problems here placed before the man of science and the engineer, if not give a clue to their final solution.

The source of power in the animal machine is invariably the stored chemical energy of vegetation, the potential energy of the hydrocarbons and other compounds contained in all plants, and capable of uniting with oxygen, to form carbonic acid, water, and salts capable of solution in water.

It is possible, but perhaps not probable, that other substances and energies forming constituents of these compounds may exist, having eluded the investigating chemist and physicist; but this is thought unlikely. We probably know precisely what enters the animal prime motor, and what are the sources of all its energies. Food and air are the two known elements of all its powers. It is also possible, but probably not the fact, that this machine may drink in from the surrounding ether some portion of its energy in forms still undetected and unsuspected. We are compelled, for the present, certainly, to assume that all the energies developed and applied in the vital machine are initially latent in vegetable matter, air and water. This organic substance is derived, by the carnivorous animals, indirectly, through the other creatures, all of which live upon vegetation directly. The organic forces of plant-life derive all energy from the inorganic world of minerals, and from the gases of the atmosphere, by utilizing the primary energy of solar rays in the chlorophyll with which every leaf is provided, as the active agent in that transformation. The vital machine thus ultimately derives all its energies from the sun.

Food is the material in which are stored the substances supplied to the vital machine as the reservoir of the potential energy from which the required energies, in various active forms, may be derived, as demanded, to perform the work of the body and the mind. It consists of a mixture of edible and other matter, the former being that part from which energy is derivable; the latter being indigestible and unassimilable, and only useful in promoting, by mechanical irritation, the action of the digestive system.

All foods contain:

Water; required for solution of nutrients.

Nutrients—protein, fats, carbohydrates.

Innutrient matter.

Protein consists of the albuminoids, and, in vegetable matter, the amides, a less valuable portion of the food. The white of egg, the fibrine of meat, and the gluten of wheat, are illustrations of albuminoid compositions.

Fats, such as those of meat, and the greases of vegetation, the oils of the animal and vegetable compounds, extractable by ether, constitute the basis of construction of the fats of the body and of a part of the nerve and brain substance.

Carbohydrates are the starches and sugars of the vegetable.

Salts are found in both animal and vegetable foods, and are, in some cases, essential elements of the compositions making up the body, though not, in the ordinary sense, digestible and nutrient.

Mineral matters constitute, in the case of the vegetable foods, the principal portion of the innutrient matter of food, and form the ash when the plant is burned. In some cases these mineral matters serve as stimulants to digestive and other physiological processes, even when not themselves in any degree digestible, and are, for that reason, essential constituents of food. It is for this reason, largely, that vegetable foods are indispensable to perfect action of the functions and to bodily and mental health. The vegetable food also, especially the fruits and grains, contain the required elements of all the compositions of the animal system in best proportion, and best arranged for utilization by man and all other except the purely carnivorous animals. Could the whole animal be used as food, including blood and nerve and bone and brain, animal food would be substantially correct in composition ; but itwould still lack the stimulating property of the other class of foods which comes of the presence of the mineral and indigestible elements.

The uses of food are mainly two: (1) To supply material for the building up and the repair and maintenance of the tissues of the body; (2) To furnish the energies required in the operation of the animal machine in their various forms and in due proportion.

The first is the direct application of a portion of the food; the second disposition of the elements of the food and their potential energy may be direct, as probably in the use of the fats, the combustion of which to carbon-dioxide and water results in the production of immediately available

energy; or it may be indirect, as where the carbohydrates are first digested and, later, consumed in similar manner to the fats; or, still more indirectly, as where the protein becomes first a part of the flesh, or of the nervous system, and, later, broken down in the course of the work of the body, serves as fuel or otherwise in the production of heat or other energy by its oxidation.

Protein forms tissue, muscular, nervous and other. Fats form a part of the nervous tissue, and carbohydrates are converted by the digestive organs into fats, and then serve the same purposes. Both the latter compounds serve as fuel or energy-storing reservoirs, contain a quantity of potential energy, which is, sooner or later, drawn upon in the development of the various energies utilized in the operations of the body and the brain. It is usually assumed that the energy demanded is that of thermal molecular motion and that the value of the foods may be measured by their calorific content or potential thermal energy. Until it is known just what energies are employed in the numerous and varied operations of the living creature, and to what extent they are severally derivable from the potential energy of the various foods, and transformable from one into another, and especially from or into thermal energy, no better method can be devised than that which assumes the value of foods, properly compounded in imitation of Nature's known proportions—as in milk for children, fruit of palatable character, and grains for adults—to be proportional to their calorific measure. Pure carbon, or the pure carbohydrates, however, are not foods in a proper sense, as they could not be converted into muscle, nerve or bone, and only serve, in themselves, for energy-storage for use by a body composed of protein largely, and of other essential matter in less proportion. On the other hand, the muscle and nerve and bone-making constituents, alone serve to build up the machine, but not to operate it. Ultimately, however, it is supposed that the stored energy of the latter class of compositions become available, and thus both, the original proportions being correct, may have a kind of measure of value in that of their fuel constituents. For highest efficiency,

the proportions of the constituents must be suitable for the individual case, and availability by digestion and assimilation, and in the provocation of all essential vital processes, is quite as essential as either of the other required [illegible] of the food.

The protein compounds are all nitrogenous, whether in the form of albumen, fibrine, casein or gluten. These compounds are fairly uniform in value. The carbohydrates differ greatly among themselves in this respect; the fats are substantially of equal value as measured by thermal contents, but differ in palatableness and digestibility, and thus in food value. Neither the carbohydrates nor the fats contain nitrogen, and they are simply useful in furnishing a supply of heat or other energy. One unit weight of carbon and one of protein yield substantially equal quantities of energy, about 14,500 *B.T.U.*, or 1,860 calories per unit weight. Its energy is sufficient to raise 2,850 tons one foot high. The same weight of carbohydrate has usually very nearly the same force-value. A similar weight of fat should have 50 per cent. more stored energy—about 4,700 foot-tons. A pound of corn-meal should supply a quantity of energy equal to two-thirds that of an equal weight of carbon, about 2,080 foot-tons, 1,360 calories.

The food consumed daily by a powerful working man contains, on the average, about 3½ ounces of protein, 6 ounces of fat and 14 ounces of carbohydrates, according to Professor Woods. Its energy measures sensibly the same as that of 2½ pounds of corn-meal. Its protein and fats come largely from the flesh-food contained in the daily ration. The carbohydrates come entirely from the vegetable constituents. Another illustrative example of a ration given by the same authority measures 3·8 ounces of protein, 5 ounces of fat, 15 ounces of carbohydrates. The energy stored in the food thus taken measured 5,400 foot-tons or 3,530 calories. A standard ration for swine contains about 7,500 foot-tons, 4,900 calories per 100 pounds weight. That for cows measures 4,600 foot-tons, 3,000 calories, approximately, per 100 pounds weight. The ration for sheep measures 5,900 foot-tons and 3,550 calories per 100 pounds.

Food-energy transformation is the office of the vital machine. The fish can traverse the water all day; the bird [illegible]ugh the air all day; man and the animals on [illegible]k all day; and it is evident that, as suggested by Pe[illegible], their tasks must be not very far different in magnitude. All exert powers approximately proportional to the volume of the seasoned working muscles employed in these tasks, which, according to various authors, is not far from about the equivalent in work of one atmosphere, fifteen pounds, per square inch of section of fibre, rising to somewhat higher figures; but all are very moderate intensities as compared with those adopted in machinery and in proportion to weights developing them. None can, therefore, find in peculiar tenacities or intensities of action of working parts a means of attaining remarkable power, even in the case of the bird, which was formerly supposed to enormously excel all other creatures in its concentration of power in mass and muscle. We seem thus reduced to the study of the methods of transformation of energy of the foods. The fact that venous blood is warmer than arterial, though very slightly, is another evidence that the transformations of matter, as well as of energy, in these processes, occur in the muscular system; and the path into which investigation must be turned would seem to be fairly well located.

Dr. Carpenter was, perhaps, the first to elaborate fully and clearly the idea that the germ of the organism is not the concentrated essence and energy of the organism and all its progeny, but that it is rather constituted as "a directive agency, thus rather representing the control exercised by the superintendent builder, who is charged with the working out of the design of the architect, than the bodily force of the workmen who labor under his guidance in the construction of the fabric." The actual constructive force, he thinks—as we now can see, very possibly, wrongly—is heat.*

* "Thus in the case of the successive viviparous broods of the *Aphides*, a germ force capable of organizing a mass of living structures which would amount (it has been calculated) in the tenth brood to the bulk of 500,000,000 of stout men, must have been shut up in a single individual, weighing perhaps

It may now be taken as certain that, as Dr. Carpenter asserted in 1850, "in some way or other, fresh organizing force is constantly being supplied *from without*" during the whole period of activity of the vital machine, which continues, by inheritance, to transmit the power of absorption and transformation and of direction of this absorbed energy, for all its various purposes, throughout the life of the whole line of its posterity, and that of the race.

Liebig, Carpenter, Grove, and others, have long ago prepared the way for the acceptance of the proposition that the organs of the animal which elaborate its powers constitute an apparatus fitted to simply divert the energy received as latent in the food and awakened by the chemical processes constituting digestion, assimilation and nutrition, and to direct it into its new channels in the form of heat, mechanical energy and vital power. Sir Benjamin Brodie found that the act of respiration, simply, did not sustain the temperature of the body, and that the action of the spinal column was essential to the normal development of heat. Helmholtz found the chemical changes greater in muscle in use than when at rest, and a larger proportion of waste, due the breakdown of tissue, to be produced. Beclard found the quantity of heat developed by voluntary muscular contraction greater when simply an effort is produced, as when grasping an object firmly, than when doing work, as by lifting the object. Matteucci found that muscles absorb oxygen and throw off carbon-dioxide when doing work, and in larger amount as more work is performed.

Dr. Flint, after a very beautiful investigation of the conditions of the muscular system and the changes of tissue, in the case of the pedestrian Weston, after a five-day's walk, as well as throughout equal periods during and before the tremendous effort which carried him over 117·5 miles at the mean rate of over four miles per hour of actual travel, concluded that "work is always attended with destruction of

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the $\frac{1}{1000}$th of a grain, from which the first brood was evolved," if the theory was true; and "the bodies of all men who have lived from the time of Adam to the present day must have been concentrated in the body of their common ancestor."

muscular substance;" "the direct source of muscular power is to be looked for in the muscle itself." He thinks that the muscular tissue "cannot be absolutely stationary, and dis-assimilation must go on to a certain extent, even if no work is done. This loss must be repaired by food to maintain life." That this is ordinarily, or at least may be, a very small proportion of the energy-effect, is evident from the well-known conditions of hybernation and by the fact that Dr. Tanner and others have fasted for forty days and more, with no great apparent loss of vital and essential strength, and seemingly at only the cost of accumulated fat disposed of as a superfluity, previously, in the spaces between the muscles. In the case of severe labor, as where a pedestrian continually exerted all his powers for days together, Flint has proven clearly that large quantities of muscular tissue are broken down.*

The proportion of nitrogenized or muscle-making food to non-nitrogenized, in the walk here referred to, was, as measured in units of energy, about as 5,700,000 foot-pounds to 39,000,000, or about fifteen per cent.; which figure will be recognized later as corroborated by other and independent methods of examination of this subject. The total absorbed energy would thus be about 11,000,000 foot-pounds per day, plus that derived by the breaking down of tissue to the extent of the total value of about 3,500,000 foot-pounds, 700,000 per day; that is to say, 11,700,000 foot-pounds of energy were supplied the system per day, when doing an extraordinarily large amount of work, both externally and internally.† But Weston is a small man, and probably ten per cent. should be added to make these figures comparable with those elsewhere given as the average for a working man, 10,000,000 foot-pounds. This gives a total of over 12,000,000 foot-pounds, or twenty per cent. of the estimated figure to be later computed for the average regular day's work. The

* "The Source of Muscular Power." New York: D. Appleton & Co. 1878.

† The vital machine consists of about forty per cent. muscle, of which a half is water, 12·5 per cent. blood, 2 per cent. brain, and the remainder is skeleton and internal organs.

food taken averaged about twenty ounces, a pound and a quarter, but was somewhat concentrated, and stimulating in more than ordinary degree.

As remarked by Professor Foster,* "from many considerations, it is extremely probable that a chemical change, an explosive decomposition of more complex into more simple substances, is the basis of a nervous impulse." The energy thus developed is largely in this case employed in conveying the impulse along the nerve and in setting up muscular or mental evolutions and applications of energy at its extremity.

The introduction of chemical actions in the production of solution of the available constituents of the food is one of the essential elements of the extraordinarily perfect utilization of all its substance, of its complete digestion, entire absorption and thorough assimilation. Only from a state of solution could complete absorption or precipitation take place. Food undergoes "profound disruption" before it can become a part of the body or furnish it energy. "It would almost seem that the qualities of each particle of living protoplasm were of such an individual character that it had to be built up afresh from almost the very beginning."†

The presence of considerable quantities of phosphorus, especially in the nervous system of the animal, indicates that chemical actions may be very rapid, and possibly may especially indicate the resultant production of peculiar material and non-material output, as the electric current of the gymnotus, if not all animals, light in the fire-fly, the vital forces of all vital machines. The presence of water in large quantity points the same way.

The blood is the carrier and distributor of all potential energy from the dissolved material of supply, and the capacity of the blood-vessels is probably something of a gauge of the quantity of energy supplied the parts to which they lead, and of the mean rate of expenditure during their period of operation and restoration to normal condition of rest. Whether the nutriment and the potential energy

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* Encyclopædia Britannica. Art. Physiology, p. 21.

† *Ibid*

thus conveyed supply energy directly, as supposed by Dr. Pavy and others,* or indirectly by the upbuilding of tissue later broken down and supplying directly the stock of energy needed for transformation, as supposed and probably experimentally proven by Dr. Flint,† the result is the same.

The influence of the form in which the potential energy is supplied the machine is well exhibited where, as in penal institutions like that of the State of New York, "experimental classes can be formed and the effect of the changes thus found practicable, observed and measured. The inverse ratio of food-supply to crime and to illness had long been recognized by students in anthropology and sociology; the fact that every variation of the quality of an ample food-supply produces an effect upon our moods, our powers and our ability to perform mental even more than manual work, is a daily observation with every one; and the suggestion has even been made that the selection of nutriments may be made to produce effects of economic importance in both directions—in making the human as well as the lower order of machine better as a motor, better as an intelligent worker, and even better as a thinker and as a moral creature—which lines of improvement are all essential to further progress in either direction. So far as both experiment and general observation have gone, at present, it may safely be stated there can be no question that the value, the power, the efficiency and durability of the mechanical and of the mental side of the vital apparatus are both influenced essentially by the nature of the material selected as the reservoir of potential energy, to be rendered kinetic and to be applied to useful purposes by it.

As indicated by Dr. Carpenter, in the middle of the nineteenth century, it would seem now certain that "*motor force* may be developed, like heat, by the metamorphosis of constituents of food which are not converted into living tissue;" while there is also no doubt that, in many cases at least, the disintegration of tissue which has completed its period of service in the organism may, precisely as does the digestion

* *The Lancet*, Nov. 25, 1876.

† *Journal of Anatomy and Physiology*, Oct., 1877.

of animal food, perform its part in the supply of potential energy to the system for utilization in vital and other operations. As the same great physicist and physiologist has stated it:

"The life of man or of any of the higher animals consists essentially in the manifestation of forces of various kinds, of which the organism is the instrument, and these forces are developed by the retrograde metamorphosis of the organic compounds generated by the instrumentality of plants.

"Thus, during the whole life of the animal, the organism is restoring to the world around both the materials and the forces which it draws from it; and after its death this restoration is completed, as in plants, by the final decomposition of its substance."

As was, perhaps, first stated explicitly, by Liebig, we find that the sources of all forces, powers, energies, in man and animals, are to be found in the food constructed by the plants out of mineral substances under the active energy of the sun's rays, which energy, becoming thus latent, is reawakened by the vital apparatus and directed into useful channels, constructing the whole animal machine, and doing all its work—muscular, thermal, electrical, vital, mental.

The quantity of energy imported into the vital machine, is, in any individual case, readily measurable. It differs greatly with the species, size, temperament and work, external and internal, of the animal, and very greatly with the efficiency of its apparatus of digestion and assimilation. While, for example, one man will live and enjoy life and do his full share of work on one pound of good food per day, another will often require two pounds or more; and, in some instances, in which disease had reduced the assimilative powers, as much as seven pounds have been demanded and still proved insufficient to supply the needed total energy of the system. For a healthy and hard-working man, Dr. Pavy gives two pounds of bread and 0·75 pound of meat as a fair ration for a day.* Moleschott gives a total of forty six ounces, or about twenty-three ounces in a dry state, and

* "Treatise on Foods."

sixty to eighty ounces of water in twenty-four hours. Voit gives 500 to 800 grams, or about seventeen to twenty-seven ounces of nutrient matter in the food taken*; and, on the same basis, eliminating wastes, the principal investigators give about 550 grams, nearly twenty ounces, as an average. Edward Atkinson gives from 2 to 2·75 pounds per day of common foods as dietaries on which life can be sustained and ordinary work done without strain; but he allows four pounds for what may be termed "good living."† Much of the food included in the bill of fare of the well-to-do citizen has no real value in nutrition; some of it is actually and often seriously detrimental, and some, possibly a large proportion, is simply superfluity and waste.

The food of a working man contains about 15 per cent. nitrogenous matter; that of a young child 20 per cent. Milk contains 25 per cent., uncombined water, as in the preceding cases, eliminated. Eighty-five per cent. of the food of the man is thus applicable to work, and 15 per cent. to muscle-making. Three-fourths of the child's food is suitable for work and production of fat; one-fourth for making muscle. An egg contains 11 per cent. fat, 17·6 per cent. albumen, and 1·5 mineral matter; or dry, 37 per cent. fat, 58 per cent. albumen and 5 per cent. minerals; *i. e.*, apparently nitrogenous matter constituted about 0·6 the total weight of the body. A large fraction of the food is thus required for work and heat, a small proportion for building up the machine, or for its repair.

Wheat is usually considered the most perfectly compounded of the grains adapted for the food of man. It contains, according to Scammel, 14·6 per cent. muscle-making elements, 66·4 per cent. heat-producing material, 1·6 per cent. nerve and brain food, and 17·4 water and waste. Oatmeal contains, respectively, 17, 50·8, 3 and 30·5 per cent. of these elements. The meats contain 20, 14, 2 and 64 per cent. Fish require little heat, obviously, and as food contain 20 per cent. muscle-making material, 1 per cent. fat,

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* *Mott's Manual.*

† Thurston's "Animal as a Prime Mover," p. 76.

5 per cent. brain and nerve food, and 74 per cent. water and waste. Oysters contain two-thirds as much solid matter of substantially the same composition. On the whole, four times as much energy is supplied in good food for heat and work as for muscle-repair, and forty times as much as for brain and nerve.

Frankland finds the energy per pound of common foods to range from 2,000 or 3,000 British thermal units in the case of the lean meats, to about 7,000 with the grains and their flours, and to over 15,000 in the case of the solid fats. The underground vegetables, which can hardly be called foods, such as potatoes, cabbage, carrots, contain three-fourths to seven-eighths their weight water, and only supply from 800 to 1,800 British thermal units of energy. In foot-pounds of dynamic power, the figures are, 600,000 to 1,400,000 for the last-mentioned substances, 1,500,000 or 2,300,000 for the lean meats, 5,000,000 to 6,000,000 for the grain foods, and 12,000,000 for the fats per pound of nutriment digested. This comparison, however, gives no clue to their values as foods and as nutriment of the vital machine, since it is known that the heat-producing value is but a part of the question, and that the power of assimilating the elements of the body and of producing muscle, nerve, brain and bone is no less essential to the maintenance of the efficiency of the machine than the production of thermal or other equivalent energies. The grains have double the value of the meats as brain and nerve foods, and the coarse vegetables one-fourth the value of the grains in this respect. Butter and lard, the best heat-producers, have no value at all as muscle and nerve material.*

Voit and others give the correct proportion of these elements in good food as about 120 grams protein, 50 grams of fats, 550 grams of carbohydrates, a total of, say, 700 grams, about twenty-three ounces per day, as the requirement of a man doing a day's work at muscular labor. This provides not far from 3,000 calories of thermal energy by oxidation. Voit gives a total required energy in thermal

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* Scammel. *Ibid.*, p. 74.

units of from 3,000 to 3,300 calories, Playfair from 3,000 to 3,700, and Atwater from 2,820 to 4,060 calories; or, collecting all the best authorities, we may say that 3,000 calories, about 12,000 B. T. U., may be taken as representative of the demand of the machine for energy when doing little external work, and 4,000 calories, about 16,000 B. T. U., when performing a hard day's work every day. This means the equivalent of one pound of ordinary coal for the first, and an equal weight of the best coal for the second case, burned completely and with, consequently, maximum production of thermal energy and dynamic power. One pound of fairly good coal, say, about 13,000 B. T. U. of energy, may be assumed as ample for the production of all the work and power, and all the active phenomena, internal as well as external, of the human machine, when doing a full day's work.

This is 10,000,000 foot-pounds, nearly, of *energy supplied.*

So far as now known, this food-supply and the oxygen required for its complete combustion, with some nitrogen and a minute quantity of mineral matter, constitute the total intake of the animal machine, except that a quart of water, more or less, is needed to dilute the circulating fluids of the system. The next question for our examination is: What amounts of energy are expended and utilized in the various processes of the operation, of maintenance and repair, and of performance of external work, useful and useless, in an average day, with its usual distribution of working time and rest?

The efficiency of the animal, considered as a machine, is now well understood to be dependent, in large measure, for any given individual, upon the character of the material in which the stored energy supplied it is presented. It is coming to be understood, also, that the same is true of the vital prime mover, considered as a thought-producer. It is well known, also, that this is an important element in the maintenance of that ideal state, "perfect health," to which we may approximate, but never absolutely reach, and the approximation to which measures approximation to maximum efficiency under otherwise most favorable possible condi-

tions. From this point of view it is interesting to study the following summary of the distribution of nutritive and of heat-producing elements in the best dietaries, according to acccepted authorities, that have been yet proposed. The nutrients, the nitrogenous matters, are classed as including the muscle of meats, the casein of milk, the gluten of grains; while the fats and carbohydrates are taken as purely heat-producing, and the following diagram and tables, from the report of 1893 of the Elmira Reformatory, gives the best condensed view of the data required that the writer has yet seen.*

The Standard Dictary for man is usually given as not far from a weight of 700 grams, of which about 60 per cent. is generally starchy food, 20 per cent. fats, and the remainder nitrogenous; the potential energy stored is about 3,650 calories.† But while the actual dietaries are commonly largely composed of animal food, it should be at all times remembered that the teachings of comparative anatomy and of general experience, so far as careful observation informs us, indicate that the vegetable starches and fats and proteins are more suitable for the animal prime motor, and even still more to the thought-machine, than the carnivorous foods.‡

It will be noted that the lower limit of supply ranges close upon 400 grams, 2,000 calories, 8,000 B.T.U., for little or

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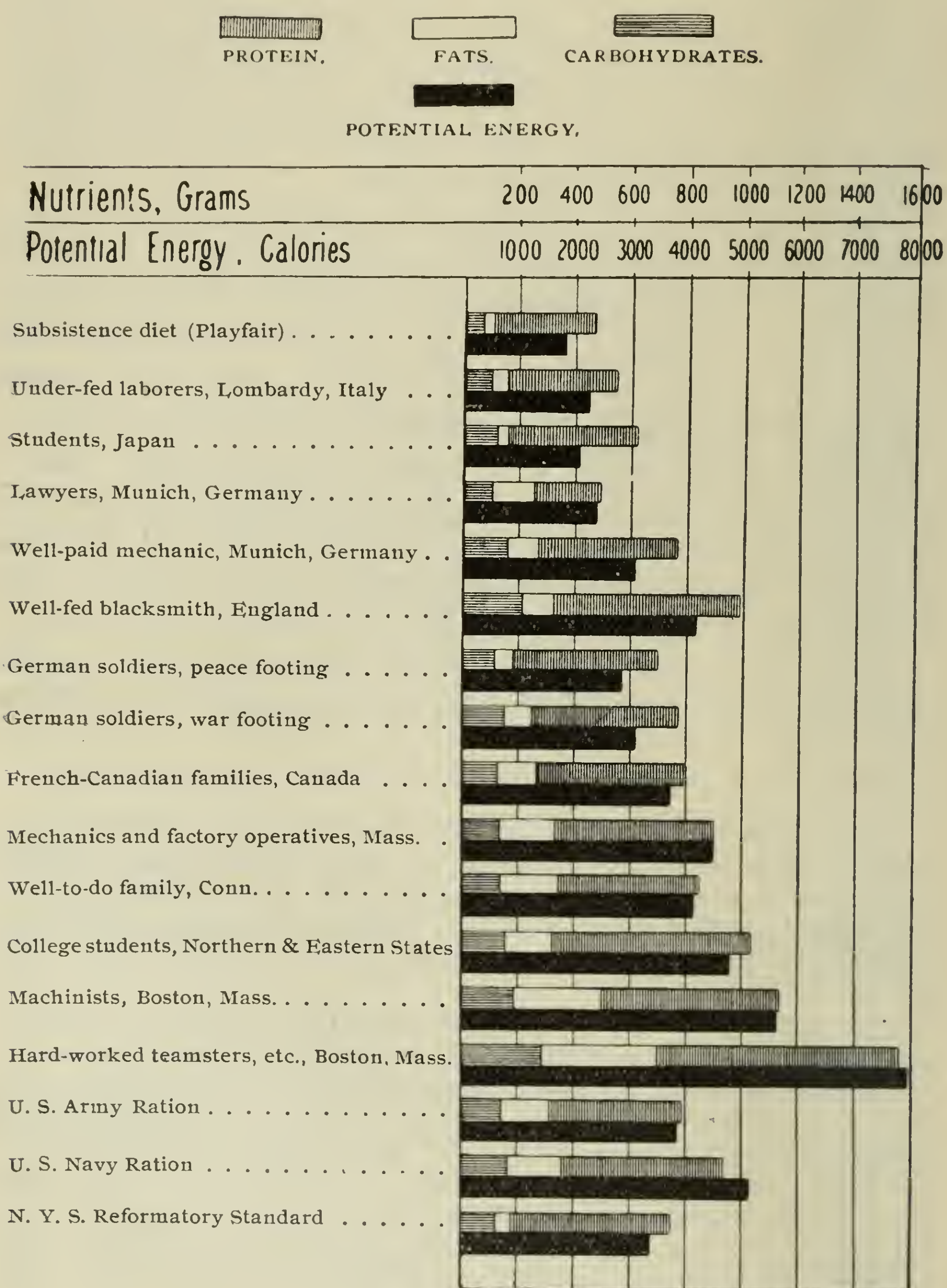
* The Eighteenth Year-Book of the New York State Reformatory, at Elmira, issued, under the supervision of its distinguished and successful superintendent, as wholly the product of the talent of its officers and of the manual skill and the taste of its inmates, contains exceedingly valuable and interesting accounts of the manual training system and trade schools there so fruitfully operated.

† For present purposes it will be sufficiently accurate to take the gram as one-thirtieth of an ounce and the calorie as four British thermal units.

‡ See particularly, Schlickeysen; Fruit and Bread, a Scientific Diet; Holbrook's translation, 1877. See, also, various papers of The Anthropological Institute of Great Britain, as that of C. O. Groom, Napier, and the address of Dr. Denis at the International Congress of Anthropology, of 1892; which papers and various researches now becoming familiar, show the influence of the character of the energy-storing material supplied the vital engine upon its power and efficiency in both fields of application of kinetic energy derived from the original store of potential.

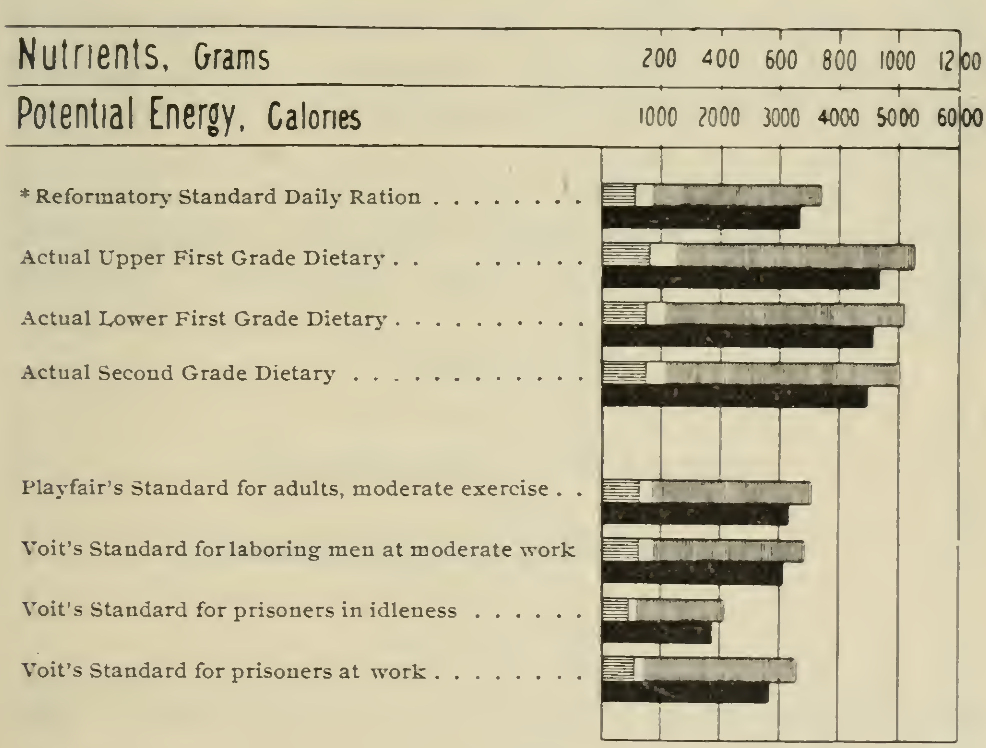
no labor; that it is not far from 600 grams, 3,000 calories, 12,000 B.T.U. for the working man; while double these figures may be reached.

I.—STANDARD AND ACTUAL DIETARIES.



On account of unavoidable waste, exact standards cannot be adopted in a practical ideal dietary, and it is universally deemed necessary to establish, beside an exact standard, an actual practical standard dietary, with somewhat increased allowance. The first table furnishes a comparison of certain daily dietaries computed principally by Prof. W. O. Atwater, and bearing upon people in various parts of the globe—together with lines indicating the theoretical standard dietary adopted in the Reformatory. The second table offers a comparison between this exact standard and the actual dietary as provided in three grades established at Elmira, and in contrast, other standards established by Playfair and Voit for adults in general, and for inmates of penal institutions.

II.—IDEAL AND ACTUAL PENAL DIETARIES.



Exact figures corresponding to these lines are presented herewith :

III.—ANALYSES OF ENERGY STORAGE.

	Nutrients, in Grams.			Potential Energy in Calories.
	Protein.	Fats.	Carbo-hydrates.	
Ref't'y Standard Dietary Daily Ration[1] . .	119	61	556	3,334
Actual Upper First Grade Ration	167	75	810	4,696
Actual Lower First Grade Ration	154	69	794	4,524
Actual Second Grade Ration	154	69	776	4,452
Playfair's standard for adults, moderate exercise	119	51	531	3,140
Voit's standard for laboring men at moderate work	118	56	500	3,050
Voit's standard for prisoners in idleness . .	85	30	300	1,857
Voit's standard for prisoners at work . . .	105	40	500	2,852

[1] All food supplies are issued according to this standard dietary, *except bread;* which is unlimited. The average consumption of bread per man is somewhat in excess of one and one-half rations per meal, thus accounting for the increase in value of the actual ration over that of the Standard Dietary, which conforms very nearly in food-values to the standards of Voit and Playfair.

An excess above 600 grams, 3,000 calories, 12,000 B.T.U., may probably be taken as representing waste in most cases; it is certainly exceptional. Deficiency is as probably indicated where the weight is less than two-thirds this figure.

The quantity of energy supplied, where the method and material of supply are suitable, may thus range between 8,000 and 12,000 B.T.U., from 6,700,000 to 10,000,000 foot-pounds per day.

[*To be continued.*]

THE LAW OF INVENTION.*

By HORACE PETTIT, of the Philadelphia Bar.

LECTURE II.

It will be interesting to note the interpretation placed by the highest Court of Appeals upon the question of "patentable invention" in some of the recent cases, for the purpose of gaining an insight into the rules observed by the Supreme Court of the United States in the determina-

* Two lectures delivered before the Franklin Institute, November 10 and 24, 1893.

	NUTRIENTS.					POTENTIAL ENERGY.
	Fats.		*Carbohydrates.*		*Mineral Matter.*	
	Per Cent.	Ounce.	Per Cent.	Ounce.	Per Cent.	Calories.
(	8·0	·51	—	—		358
]	21·7	7·94	—	—	0·8	2,608
	23·2	1·86	—	—	0·7	834
]	76·5	·76	—	—	0·8	205
]	17·0	·34	46·0	·92		246
]	1·9	3·19	55·5	93·24	1·0	13,417
]	0.2	·12	19·1	11·46	0·9	1,489
(( ]]	0·2	0·4	6·0	1·17	0·8	192
]	1·1	·05	75·6	3·78	0·6	518
(	7·1	·02	68·1	·17	2·0	29
I	2·1	·22	57·4	6·02	3·6	1,042
I	2·5	.01	67·0	·17	2·0	24
I	0·4	·01	79·4	1·39	0·4	178
?	—	—	63·0	18·90		2,197
		15·07 2·15		137·22 19·60		23,337 3,334
	. . . . .	61	. . . . .	556		
E		1·86		54·39		7,827
		16·93 2·42		191·61 27·37		31,164 4,452
	. . . . .	69	. . . . .	776		
C T S	—	—	96·7	4·35	0·8	507
		16·93 2·42		195·96 27·99		31,671 4,524
	. . . . .	69	. . . . .	794		
C S D C	—	—	96·7	3·12	0·8	363
B	85·0	·96	0·5	·01	3·5	254
C	6·8	·54	8·9	·71	4·5	583
		18·43 2·63		199·80 28·56		32,871 4,696
	. . . . .	75	. . . . .	810		

eat" or other grain, supplying but about 1,400 calories per

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NEW YORK STATE REFORMATORY DIETARY.

STANDARD DAILY DIETARY.

	Sunday.			Monday.			Tuesday.			Wednesday.			Thursday.			Friday.			Saturday.			*Weekly Total.*
*	b	d	s	b	d	s	b	d	s	b	d	s	b	d	s	b	d	s	b	d	s	Ounce.
C. Corned Beef	1·6						1·6						1·6			1·6						6·40
Beef					12			6									6			8		32·
Mutton											8											8·
Pork (fat)														1								1·
Kopf's Pea Soup		2																				2·
Bread	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	168·
Potatoes	6				12		6	4		6	4		6			6			6	4		60·
Onions								½		½	½								½	½		2·50
Turnips								1			2									2		5·
Carrots								1			1½									1½		4·
Parsnips								1			1½									1½		4·
Beets								½			½									½		1·50
Tomatoes																	2½					2·50
Flour					½						1½						1½			1½		5·
Oatmeal†								¼														·25
Beans				4				½						6								10·50
Barley								¼														·25
Rice								¾									1					1·75
Molasses																						31·
Totals, one week																						344·65
Totals, one day																				49·24		
Bread (actual average consumption per man per week in excess of Standard Ration)																						98·
Totals, one week																						442·68
Totals, one day																				63·24		
Additional for Upper and Lower First Grades.																						
Coffee	¼			¼	¼		¼			¼	¼		¼	¼		¼			¼	¼		2·75
Tea			⅛			⅛			⅛			⅛			⅛			⅛			⅛	·88
Sugar	¼		¼	¼	¼	¼	¼		¼	¼	¼	¼	¼	¼	¼	¼		¼	¼	¼	¼	4·50
Totals, one week																						450·78
Totals, one day																				64 40		
Additional, Upper First Grade.																						
Coffee		.2						.2									·2					·60
Sugar		.2	⅜			⅜		.2	⅜			⅜			⅜		·2	⅜			⅜	3·23
Dried Apples			⅝						⅝						⅝						⅝	2·50
Currants						¾						¾						¾				2·25
Butter			⅜									⅜						⅜				1·13
Cheese						2			2						2						2	8·00
Totals, one week																						468·49
Totals, one day																				66·92		

TABLE OF FOOD VALUES.

	Refuse, Bones, Skin, etc.	*Water.*	NUTRIENTS. *Protein.*		*Fats.*		*Carbohydrates.*		*Mineral Matter.*	POTENTIAL ENERGY.
	Per Cent.	Per Cent.	Per Cent	Ounce.	Per Cent.	Ounce.	Per Cent.	Ounce.	Per Cent.	Calories.
C. Corned Beef		62·0	30·0	1·92	8·0	·51	—	—		358
Beef	19·7	44·0	13·8	4·41	21·7	7·94	—	—	0·8	2,608
Mutton	20·0	42·9	37·1	2·97	23·2	1·86	—	—	0·7	834
Pork (fat)	10·4	9·5	2·8	·03	76·5	·76	—	—	0·8	205
Kopf's Pea Soup			21·0	·42	17·0	·34	46·0	·92		246
Bread		32·7	8·9	14·95	1·9	3·19	55·5	93·24	1·0	13,417
Potatoes	10·0	68·0	1·8	1·08	0.2	·12	19·1	11·46	0·9	1,489
Onions, Turnips, Carrots, Parsnips, Beets, Tomatoes	10·0	81·0	2·0	·39	0·2	0·4	6·0	1·17	0·8	192
Flour		4·6	11·1	55	1·1	·05	75·6	3·78	0·6	518
Oatmeal†		7·7	15·1	·04	7·1	·02	68·1	·17	2·0	29
Beans		13·7	23·2	2·44	2·1	·22	57·4	6·02	3·6	1,042
Barley		18·0	10·5	·03	2·5	.01	67·0	·17	2·0	24
Rice		12·4	7·4	·13	0·4	·01	79·4	1·39	0·4	178
Molasses			—	—	—	—	63·0	18·90		2,197
Totals, one week				29·36		15·07		137·22		23,337
Totals, one day				4·19		2·15		19·60		3,334
Standard Daily Ration—Grams	....	....	....	119	....	61	....	556		
Bread (actual average consumption per man per week in excess of Standard Ration)				8·72		1·86		54·39		7,827
Totals, one week				38·08		16·93		191·61		31,164
Totals, one day				5·44		2·42		27·37		4,452
Actual Second Grade Daily Ration—Grams	....	....	....	154	....	69	....	776		
Sugar (Additional for Upper and Lower First Grades)		2·2	0·3	·01	—	—	96·7	4·35	0·8	507
Totals, one week				38·09		16·93		195·96		31,671
Totals, one day				5·44		2·42		27·99		4,524
Actual Lower First Grade Daily Ration—Grams	....	....	....	154	....	69	....	794		
Sugar (Additional, Upper First Grade)		2·2	0·3	·01	—	—	96·7	3·12	0·8	363
Butter		10·0	1·0	·01	85·0	·96	0·5	·01	3·5	254
Cheese		41·3	38·4	3·07	6·8	·54	8·9	·71	4·5	383
Totals, one week				41·18		18·43		199·80		32,871
Totals, one day				5·88		2·63		28·56		4,696
Actual Upper First Grade Daily Ration—Grams	....	....	....	167	....	75	....	810		

* b—breakfast. d—dinner. s—supper.

† The writer has, as a matter of experiment, lived for long periods of time on about twelve ounces per day of oatmeal (dry) or the equivalent in "cracked wheat" or other grain, supplying but about 1,400 calories per day, and, leading sedentary life, found this allowance ample. This is also the least costly of all foods, and the writer has known young men to live on 60 cents a week, making up the dietary of grain foods, mainly.

tion of this question. A careful examination evinces the fact that the judges are governed to a very large extent, if not entirely, by the rules which governed their worthy predecessors in deciding some of the leading cases where this question was involved. The tendency of the courts still to be governed by "practical results" in cases somewhat doubtful is apparent in the recent decisions; never substantiating the patent, otherwise invalid, on account of the practical achievements and the commercial success of the invention, but employing the fact of *practical success*, in cases otherwise doubtful, as an additional reason for supporting the validity of the patent.

One of the most interesting decisions of the Supreme Court of the United States within the last year or two, is that of Washburne & Moen Company *vs.* The "Beat-'em-all" Barb Wire Company, otherwise known as the Barb Wire Patent cases, reported in 143 U. S. Supreme Court Reports, p. 275. etc., decided February 29, 1892. This decision reversed the finding of the court below, and held the Glidden patent Nos. 157, 124, November 24, 1874, for an improvement in wire fences, to be valid.

I will be pardoned if I refer to this case somewhat in detail, which I do, believing the facts connected with the attempted anticipation of the patent to be instructive.

The claim of the patent is as follows:

"A twisted fence wire having the transverse spur wire *D* bent at its middle portion about one of the wire strands *a*, of said fence wire, and clamped in position and place by the other wire strand *z*, twisted upon its fellow, substantially as specified."

The appeal was from the decree of the Circuit Court of the United States for the Northern District of Iowa, which held that the patent was invalid. The bill filed relied upon certain decrees obtained in the courts of other districts against other defendants, and which were claimed to have established the validity of the patent. The main defence was that the invention was anticipated, and that the invention, in view of the anticipations, was not patentable.

When it is recollected to what an enormouns extent this

wire fence has been employed in the last few years throughout the vast plains of the West, as well as to a very large extent throughout the East, and when the fact is appreciated that the boundless plains by this means have been readily subdivided into large pasture fields for cattle, the fence operating as an effectual means for retaining the cattle in defined limits, and from straying perhaps for many miles from the ranches to which they belong, as they formerly did, it will be understood why the case was so hotly contested.

What did the patent cover? Nothing but a short transverse wire, coiled at its central portion about one of the wire strands of a twist of wires with its free ends projecting in opposite directions, the other wire of the strand serving to bind the spur wire in position to prevent lateral displacement. It was on this simple little contrivance that the great minds of the judges of the Supreme Court of the United States were called upon to pass. The defendants did not deny that they made a fence similar to that of the patentee. It was admitted that they did. A vast amount of testimony, documentary and oral, was produced. The strongest evidence in the case, to my mind, was the alleged anticipating patent granted to Michael Kelly, February 11, 1863, which was over five years in advance of the date of Glidden application. Kelly took small, flat pieces of iron or steel, each provided at its centre with a hole the size of the wire, so that they could be introduced on the wire. These pieces were strung on the wire at distances about six inches apart, and were compressed laterally by a blow of the hammer so as to flatten the hole and lock, as it were, these spurs upon the wire. He described the spur, or thorn, as being provided mainly upon a single strand of wire, though he said in his specification, and illustrated the construction in one of the drawings: "I can, where it is desirable *to increase the strength of the wire*, lay another wire of the same or a different size alongside of a thorn wire, and can twist the two by any suitable mechanism." He did not say that the twisting of these two wires was for the purpose of holding the spur in position and preventing lateral displacement, which Glidden said in his

patent would be the effect of the twisted wires, and the purpose for which he, Glidden, employed the additional wire; but Kelly employed it, as he states, "to increase the strength of the wire." It will be clearly seen, however, that even though Kelly did not say so, the effect of the wires thus twisted must have been the same, and must have aided in holding the spur in position, and preventing lateral displacement.

Mr. Justice Brown said, *inter alia*, in deciding the case: "The vital difference in the two patents is in the shape of the barb itself. In one case (Kelly) a flat bit of metal is used of an elongated diamond shape, through which a hole is pierced, by means of which it is strung upon the wire requiring something more than the aid of a second wire twisted upon the first, to render it immovable. In the other, the barb is a piece of wire coiled about one of the fence wires, and held rigidly in place by the twisting of another wire about the first." Substantially, the difference between Kelly and Glidden was that Kelly made his spur out of a piece of flat metal with a hole in the centre, placing it between two strands of twisted fence wire (in the alternative construction) and hammering down the sides to more firmly lock it in position, while Glidden made his spur out of a short piece of wire, giving it one or two twists around one of the strands of the fence wire and holding it in position from lateral displacement by the other twisted strand of fence wire.

This brings us down to what the Supreme Court of the United States construed to be *invention* in the early part of last year. It was more than the exercise of mechanical skill; it was more than calling into play the exercise of the constructive faculties. In the opinion of the court, it required the employment of the *inventive* faculties.

The views of the court upon the question of the patentability of the Glidden barb wire may be gathered from the following short extract from the decision:

Mr. Justice Brown, upon this point, said: "The inventions of Hunt and Smith (other references less pertinent than Kelly) appear to be scarcely more than tentative and

never to have gone into general use. The sales of the Kelly patent never seem to have exceeded 3,000 tons per annum, while plaintiff's manufacture and sales of the Glidden device (substituting a sharp barb for a blunt one), rose rapidly from fifty tons in 1874 to 44,000 tons in 1886, while those of its licenses in 1887 reached the enormous amount of 173,000 tons. Indeed, one who has travelled upon the western plains of this continent cannot fail to have noticed the very large amount of territory enclosed by these fences, which otherwise, owing to the great scarcity of wood, would have to be left unprotected.

"Under such circumstances courts have not been reluctant to sustain a patent to the man who has taken the final step which has turned a failure into a success. In the law of patents it is the last step that wins. It may be strange that, considering the important results obtained by Kelly in his patent, it did not occur to him to substitute a coiled wire in place of the diamond shaped prong, but evidently it did not; and to the man to whom it did ought not to be denied the quality of inventor. There are many instances in the reported decisions of this court where a monopoly has been sustained in favor of the last of a series of inventors, all of whom are groping to attain a certain result, which only the last one of the number seemed able to grasp."

Mr. Justice Brown here cited the case of the Webster Loom Company *vs.* Higgins, 105 U. S. 580, where an improvement in looms for weaving pile fabrics, consisting of such a new combination of known devices as to give to a loom the capacity of weaving fifty yards of carpet a day, when before it could only weave forty yards, was held to be patentable.

The barb wire case will suffice to illustrate what, in the opinion of the Supreme Court, in 1892, was necessary to constitute patentable invention.

The laymen who may be interested in knowing the amount of research which is involved in the defence of a well-tried patent suit, would do well to read the testimony produced in this case, as a fair illustration. The history of barbed wire fences was, in these cases, for the first time

completely set out. No such care is exercised in the compilation of facts in the preparation of the most authentic biographies of illustrious men, or in the compilation of detail in the preparation of the history of a great people. Not that I mean to say that this case—although most carefully prepared by eminent counsel—is a more shining example than other important cases, but merely cite it as an instance; and would also advise those seeking for such information to carefully read the testimony produced on the part of the defence in the attempt to invalidate the Bell telephone patent.

Since the jurisdiction upon appeal in patent suits has been generally taken away from the Supreme Court of the United States and conferred upon the Circuit Courts of Appeals of the various districts, it will be noted from the general line of decisions of the latter, that they have followed fairly closely the path which had previously been hewn out through the underbrush of difficulty by the Supreme Court of the United States, after many years of arduous labor.

"AFTER THE FACT."

The case of Webster Loom Company *vs.* Higgins, and the barb wire case, it may be noted, in passing, show clearly that in these two important cases of early and of late date respectively, the court was not influenced by a fault which many of the courts in deciding the question of patentability seem to have fallen into, of forming an opinion regarding the patentability of an invention "after the event," or rather "after the fact;" after the way is opened out, showing how to overcome the obstacles which now seem very clear indeed, though before a cloud intervened, which required the eye of the *inventive* faculty to penetrate. When the cloud is removed it is hard to appreciate that it ever existed, and, consequently, the courts are often led, in determining an apparently "border-line" case, to decide that the change was one of *mere mechanical skill*, and not one of invention. Although the invention may have resided in some apparently trifling change, it has *bridged the gap* between failure and success. It has opened up hitherto

unknown resources; viewed "*before* the fact or event," there was no way of accomplishing the end in the desired manner except through the assistance of the *inventive* faculty. Viewed *after* the fact the means employed for bridging the gap seemed apparent and simple, as do all the tricks of the prestidigitateur when explained, yet the courts *after the fact* frequently fail to conceive that there was invention in the device.

The case of Webster Loom Company *vs.* Higgins is here directly in point. The change from the old construction was apparently trifling when once known, but it required an inventor to make that change. In this case, it was said, that it was plain from the evidence and from the fact that it was not sooner adopted and used, that it did not for years occur in this light to even the most skilled persons. It may have been under their very eyes, they may almost be said to have stumbled over it; but they certainly failed to see it, to estimate its value and to bring it into notice. Now that it has succeeded, it may seem very plain to any one that he could have done it as well. This is often the case with inventions of the greatest merit. It may be laid down as a general rule, though not, perhaps, as an invariable one, that if a new combination and arrangement of known elements produce a new and beneficial result never attained before, it is evidence of invention.

In Consolidated Safety Valve Company *vs.* Crosby Company, 113 U. S. 157, it was said that Richardson's invention brought to success what prior inventors had essayed and partly accomplished. He used some things which had been used before, but he added just that which was necessary to make the whole a practical, valuable and economical apparatus. He added to his valve that part which was necessary to make the valve a success, and which very part the others lacked.

The fact that a device has gone into general use, and displaced devices for like purposes, does not establish the fact that the later device involves patentable invention. It may, however, always be considered, and when the other facts in the case leave the question in doubt, it is sufficient

to turn the scale. (Smith *vs.* Goodyear Company, 93 U. S. 486; Magowan *vs.* New York Belting Company, 141 U. S. 332.)

The question, What is invention? or sufficiency of invention to support a patent? is one upon which volumes have been written, and volumes more could be written, but it is unnecessary here is this brief paper to consider the question further. Sufficient has been said to point out the difficulties of formulating any fixed rule for determining invention, but from the rules which do exist, one skilled in the particular branch can, with a fair amount of accuracy, determine the question. To assume the dignity of a patentable invention the subject must be capable of involving the exercise of the *inventive* faculties, as contradistinguished from the *constructive* faculties, of the mind. Ingenuity must be apparent, but it matters not to what degree; it may be but the *spark* of ingenuity. It matters not whether the invention is the result of long and laborious research and study or whether it was conceived by a *single flash* of the inventive faculties.

APPLICATION FOR LETTERS-PATENT.

Having sufficiently considered, for the purposes of this paper, the question What is patentable invention? before attempting to discuss the different classes into which patents are properly divided, let us pause for one moment to consider in a cursory manner the nature of the proceedings in application for patents.

The application comprises a petition to the Commissioner of Patents, a power of attorney to the solicitor or attorney (where a solicitor or attorney is employed), a specification and claim(s), and an affidavit by the applicant setting forth that he believes himself to be the inventor, that the invention has not been on sale or in public use in the United States for more than two years prior to the date of his invention, and other detail. If the invention has been patented abroad prior to the date of application here, the countries and the dates of these patents must be stated in the oath. If the invention has been patented in foreign countries prior to the date of the issue of the United States pat-

ent, the term of the United States patent will be limited to the term of the foreign patent having the shortest term to run. As most foreign patents bear date as of the date of filing, great care must be exercised where the inventor desires to take out foreign patents, that the foreign applications shall not be filed before the United States patent issues; for, should the United States patent issue before the foreign is filed, the validity of the foreign patent in some countries will be affected. The better practice, and the one most generally followed in taking out a series of United States and foreign patents, is to issue in this country and file abroad on the same date. This is the general rule; of course, the laws vary somewhat in the different countries, and the applicant must be governed by the particular countries in which he is making application for protection.

The applicant should not expect to secure a patent in this country within five months from the date of filing; a patent is comparatively rarely issued within that time. In cases where exceptional dispatch of business is exhibited, both on the part of the Patent Office and on the part of the attorney, the time occupied might be something less, sometimes three months will see a patent through.

Sometimes it is the desire of the patentee to delay as long as possible the issue of the patent, for purposes of his own, and various methods of delay are resorted to for this purpose. I have personal knowledge of a patent on a feather duster which was not issued until thirteen years and nine months after the date of filing. The application for the Berliner patent, belonging to the American Bell Telephone Company, was filed June 4, 1877, and was not issued until November 17, 1891, a period of fourteen years and five months after the date of filing.

The term of a United States patent does not commence to run until the date of issue, and the patentee has no exclusive right in and to his invention until the date of issue, from which time, provided that his patent is valid, and that the invention has not previously been patented abroad, he has the exclusive right to the invention for the term of seventeen years.

The specification must describe the invention accurately and specifically, so that one skilled in the art to which it pertains can make and use the same. The claims are most important and must set forth specifically the essential elements or features which the applicant considers to constitute his invention; no more, no less.

CAVEAT.

If an inventor has conceived, but only partially completed his invention, and is apprehensive that before he shall complete the same, another may file an application for letters-patent for the same invention, what is he to do? The law provides him a remedy. He can file what is termed a "caveat."

A great many inventors, principally the inexperienced, of which there are a great number—have acquired the idea from some source that a caveat is a *cheap patent.* This is not the fact. A caveat is for *one* purpose, viz: *notice.* It gives no right to the caveator to prevent others from making, selling, or using his invention, during the life of the caveat, or at any other time, until he has secured and has had actually issued to him letters-patent. The law relative to caveats merely says to the inventor, substantially: If you desire further time to *mature* your invention you can file a caveat in the Patent Office, and if an application for a like invention is made during the life of the caveat you will receive notice of the same, whereupon you must file your application within a limited period specified.

Section 4,902 of the Revised Statutes says, substantially, that any citizen (or alien, if he has resided one year in the United States next preceding the date of filing, and has declared his intentions to become a citizen of the United States), who desires further time to *mature* his invention or discovery may, on payment of the fees file a caveat setting forth the design and distinguishing characteristics of his invention, and praying protection until he may have matured his invention, which caveat will be filed in the confidential archives of the Patent Office. A caveat is granted for *one* year from the date of filing, but may be renewed

from year to year, at the will of the caveator, If an application is filed for the same invention during the life of the caveat, notice is given to the caveator and he must file his application for a patent in three months from the time allowed for receipt of same by mail. If the claims are for the same invention an interference will be declared, and the case will be heard as on the usual interference proceedings in the Patent Office.

Cases have arisen where it has been shown by proof that the caveator did not receive the notice sent him by mail, and it has been held that as it was no fault of the caveator that he did not receive the notice he should not suffer, but that he was entitled to contest in the Patent Office the priority of his invention over the claims of the man who secured the patent, and if he should sustain his claims to priority he would be entitled to a patent. (Frevert *vs.* Gahr, 1873, 3 *Official Gazette*, 660). This was also substantially held in Ware *vs.* Bullock (1874, 7 *Official Gazette*, 39) Phelps *vs.* Brown (1859, 4th. Blatchf. 352).

The rule in reference to caveats applies only to notice of applications which are filed while the caveat is alive. Of those filed before the caveat and after it has expired by limitation, the caveator is not entitled to notice.

CLASSES OF PATENTS.

Patents are granted under Section 4,886 of the Revised Statutes for four classes of inventions therein noted, viz: an *art*, *machine*, *manufacture and composition of matter*. These may be resolved for the purposes of more condensed classification into three classes, viz: *process patents*, *machine patents* and *product patents*. An art in the patent law sense of the word is a method or process; machines form a class by themselves; a manufacture and composition of matter may be resolved into one class, and termed a *product*.

In addition to these classes of patents the law also provides for the granting of *design patents*, which will be hereinafter briefly referred to.

Process.—The word "art" employed in Section 4,886, as interpreted by the courts, has a much more restricted

meaning than the word as defined in the dictionaries. Again, a *process* must be distinguished from a *principle*. A principle is *not* patentable; a process is.

In determining what is, and what is not, a patentable process, necessarily some very fine points and distinctions become involved. The mere use or employment of a particular element of nature to do or operate a particular thing would *not* in itself be a *process* within the contemplation of the Act. In order to render it patentable, the thing achieved must in all cases, have involved the exercise, or been capable of involving the exercise of the inventive faculties of the inventor or discoverer; the adaptation or use of an electric current for printing intelligible characters at a distance conveys the distinction very fully to the mind, in a negative manner. This was decided by the Supreme Court *not* to be a patentable process. The great case of O'Reilly *vs.* Morse (15 How., 61), and the celebrated decision of Chief Justice Taney in this case has been referred to in very nearly all of the decisions since that date where the question of *process* was involved.

If a force of nature known or unknown is applied to a material physical object in a new way and brings about new physical results, it is clear that in order to accomplish this the faculties of the discoverer, known as the *inventive* faculties, must have been brought into requisition. The force of nature itself has with the material or physical object operated in a manner in which the two elements have never before been known to have operated. It is not always necessary that the resulting product shall be a *new* product, so long as the operation of the known force upon the physical or material object is new in the manner described and employed. (Foote *vs.* Silsby, 1849, 1 Blatchf. 445.) The practical application of a known force to a new object is a new art (Whitney *vs.* Mowry, 1867, 2 Bond. 45), and the practical application of a new, or heretofore unapplied natural force is a patentable process (Roberts *vs.* Dickey, 1871, 1 Off. Gaz. 4). A new mode of using old apparatus may constitute a patentable process. (Lawther *vs.* Hamilton, 1888, 42 Off. Gaz., 487.) Mr. Robinson in his work on Pat-

ents, Vol. I, Sec. 165, says: "An art may be either a force applied, a mode of application or the specific treatment of a specific object." An art may be fully within either of the three great fundamental groups of means according to the number of its essential factors and the subject of the process or discovery.

It is clear that the effect produced must be a *physical* effect.

The art of vulcanizing India rubber by subjecting it to a high degree of heat when mixed with sulphur and a metallic salt was a patentable process. Neilson's method of applying the hot blast to furnaces by forcing the blast through a vessel or receptacle situated between the blowing apparatus and the furnace, and heated to a red heat, was a patentable process. These patents were sustained after very able arguments on both sides.

In the case of Corning *vs.* Burden (15 How., 267), the court said: "A process *eo nomine* is not made the subject of a patent in our Act of Congress; it is included under the general term, 'useful art.' An art may require one or more processes or machines in order to produce a certain result or manufacture. The term 'machine' includes every mechanical device or combination of mechanical powers and devices to perform some function and produce a certain effect or result. But where the result or effect is produced by chemical action, by the operation or application of some element or power of nature, or of one substance to another, such modes, methods or operations are called 'processes.' A new process is usually the result of a discovery; a machine, of invention. The arts of tanning, dyeing, making waterproof cloth, vulcanizing India rubber, smelting ores and numerous others are usually carried on by process as distinguished from machines." Mr. Walker, in his work on patents, Section 6, defines the patent law meaning of a proces to be, "an operation performed by rule to produce a result by means not solely mechanical. Robinson on Patents, Section 159, defines it as follows: "An art or operation is an act or series of acts performed by some physical agent upon some physical object and producing in such

object some change either of character or of condition, it is also called a 'process' or a 'mode of treatment.'"

Mr. Justice Bradley in deciding the celebrated case of Tilghman *vs.* Proctor (102 U. S. 707), defined a process as follows: "Whoever discovers that a certain useful result will be produced in any art by the use of certain means is entitled to a patent for it, provided he specified the means."

In O'Reilly *vs.* Morse (15 How. 119), the court decided the eighth claim, which attempted to cover the use of the motive power of an electric or galvanic current for marking or printing intelligible characters at a distance, invalid and *not* constituting a *patentable process.* It was a claim for a new application of the electric current for that particular purpose. The court held that the claim was too broad and not warranted by law. Chief Justice Taney, in delivering the opinion, said: "No one, we suppose, will maintain that Fulton could have taken out a patent for his invention for propelling vessels by steam, describing the process and machinery he used, and claimed under it the exclusive right to use the motive power of steam, however developed for the purpose of propelling vessels. * * * Neither could the man, who first discovered that steam might, by a proper arrangement of machinery, be used as a motive power to grind corn or spin cotton claim the right of the exclusive use of steam as a motive power for the purpose of producing such effects." The learned discussion of the question of patentable process entered into by Mr. Justice Bradley in his decision of Tilghman *vs.* Proctor, above cited, has rendered the case justly celebrated.

As early as 1813 it was discovered by an eminent French chemist, M. Chevreul, that ordinary fat, tallow and oil were chemical compounds, and consisted of a base which has since become known as glycerine, and of different acids, termed generally *fat acids*, but specifically stearic, margaric and oleic acids. These acids in combination severally with the base glycerine, form, respectively what are termed stearine, margarine and oleine. These have all come to be valuable products, and the base glycerine when purified is a desirable article for many uses.

In 1853 Mr. Richard A. Tilghman, of Philadelphia, the complainant in the case, discovered that these fat acids could be separated from the base, glycerine, without injury to the glycerine, by the single and simple process of subjecting the neutral fat, while in intimate mixture with water, to a high degree of heat and under sufficient pressure to prevent the water from being converted into steam, without the employment of any alkali, or sulphuric acid, or other saponifying agent. The principal conditions were a constant and intimate commixture of the fat with the water, a high degree of heat, and a pressure sufficiently powerful to prevent the conversion of the water into steam. By this operation the fat acids were separated from their base, glycerine, and each element took up the requisite equivalent of water necessary for its separate existence; the glycerine, in solution, separated itself from the fat acids by settling to the bottom when the mixed products were allowed to stand and cool. A chemical change took place in consequence of the presence of water and the active influence of heat and pressure upon the mixture. The claim of the patent was as follows:

"The manufacture of fat acids and glycerine from fatty bodies by the action of water at a high temperature and pressure."

The patentee described in his specification a preferable construction of machinery for carrying out his process, referring also to the fact that certain other constructions could be employed. The defendants employed a different machine in carrying out the process from that described in the patent, but certainly did manufacture fat acids and glycerine from fatty bodies by the action of water at a high temperature and under pressure. They did employ some lime, but not enough to materially affect the process, and the degree of temperature employed by them was not the degree of temperature preferably used by the patentee. After a careful review of the facts and the law in an opinion by the late Mr. Justice Bradley, the claim was decided valid. In deciding the case he said, *inter alia*, "Had the process been known and used before, and not been Tilghman's

invention, he could not then have claimed anything more than the particular apparatus described in his patent, but being the inventor of the process, as we are satisfied was the fact, he was entitled to claim it in the manner he did." And after reviewing the leading cases upon the subject, such as Corning *vs.* Burden, Neilson *vs.* Thompson and O'Reilly *vs.* Morse, he further said:

"It seems to us that this clear and exact summary of the law affords the key to almost every case that can arise. Whoever discovers that a certain useful result will be produced in any art by the use of certain means is entitled to a patent for it, provided he specifies the 'means.' But everything turns on the force and meaning of the word 'means.' It is very certain that the means need not be a machine, or an apparatus; it may be, as the Court says, a process. A machine is a thing. A process is an act, or a mode of acting."

From this brief review of the subject of "process patents," we may conclude by saying that a process may be said to be a directing or training of a force in a given manner through the medium of physical agents applied to material objects whereby are produced material effects.

Machine Patents.—The question "What is a *machine?*" is not so abstruse as the question involved in the consideration of "What is a process?" Every one knows what a machine is. In the common acceptation of the term, it is a device composed of one or more parts for performing mechanically certain operations; as to whether the machine is new or not, or sufficiently novel to render it patentable over the prior art, is the important question involved in most cases in which machine constructions are concerned. Patents are constantly granted for *improvements* upon machines in their minutest details, provided the improvement is novel and useful and is capable of the exercise of the inventive faculties. The word machine, in the patent law sense, is broader than in the ordinary acceptation of the term.

Manufacture.—This is a very broad term, as broad almost as its derivation implies, not including, however, machines

or compositions of matter. Under this class patents have been granted for the construction of houses, and other constructions of buildings. This will give some idea as to the extent to which the term has been carried in the granting of patents.

Composition of Matter.—A composition of matter is usually a product formed by the chemical action of its ingredients, though it may be a product composed of various parts of matter mechanically united. A composition to be patentable must, in its entirety, produce different results from the aggregate, independent results of the respective ingredients. The ingredients in the combination must lose their individuality and produce different effects in the combination than they produce separately and as independent organisms. This class opens a wide field for litigation, as well as controversy, in the applications for patents. A *composition* may be composed of, let us say, five ingredients. A composition may subsequently be invented or discovered in which like or better effects can be produced in the product by leaving out one of the material ingredients of the other product; and thus will be composed of four ingredients only. Yet this composition will be patentable, notwithstanding the existence of the former composition, and will not infringe the former composition if there is in it no equivalent for the fifth ingredient of the first composition, and if the eliminated fifth ingredient performed an essential and material function in the old invention. In this view of the case, it must be presumed that the new composition produces a somewhat different result. From this one illustration it can be seen how large a field for litigation and controversy exists. This illustration is an extreme case, though a true one.

It will be unnecessary to further consider the subject of "composition of matter" here, or to dwell at greater length upon the consideration of the four classes over which we have briefly passed.

The Hon. Commissioner of Patents Butterworth in *Ex Parte* Blythe (1884, 30 *Official Gazette*, 1,321), suggests that there exist under Section 4,886, of the Revised Statues,

eight classes of patents, instead of the four mentioned, constituting the additional four by adding to each of the original four classes the word "*improved*," viz.: a new art, a new machine, a new manufacture, a new composition of matter, an improved art, an improved machine, an improved manufacture and an improved composition of matter, making eight in all. This, as it is seen, is a mere duplication of the four original classes with the word "improved" added.

DESIGN PATENTS.

This class of patents is almost too broad a subject to touch upon in the remaining time allotted to me. Suffice it, however, to briefly note that it is provided for in a separate section of the Revised Statutes and is distinct from the classes included in Section 4,886.

Section 4,929 provides as follows:

"Any person who, by his own industry, genius, efforts, and expense, has invented and produced any new and original design for a manufacture, bust, statue, *alto-relievo* or *bas-relief*, any new and original design for the printing of woollen, silk, cotton, or other fabrics; any new and original impression, ornament, pattern, print, or picture to be printed, painted, cast, or otherwise placed on or worked into any article of manufacture; or any new, useful, and original shape or configuration of any article of manufacture, the same not having been known or used by others before his invention or production thereof, or patented or described in any printed publication, may, upon payment of the fee prescribed, and other due proceedings had the same as in cases of inventions or discoveries, obtain a patent therefor."

A patent for a design differs at least in one important respect from patents of the other classes heretofore noted and provided for under Section 4,886, in that the invention receives its protection, not on account of its *functional utility*, but on account of its *appearance* and *ornamental effect*. In other words the classes provided for in Section 4,886 are of utilitarian value, while that provided for in Section 4,929 is of value as an *ornament* or on account of its *pleasing effect*.

For some strange reason the word useful became incorporated in Section 4,929, it says: "Any new, *useful* and original shape or configuration of any article of manufacture." But by judicial alchemy this word "*useful*" has been decided to mean not useful in a *functional* sense but that it means *ornamental utility*. It seems to me clear that the word is there by mistake, but it cannot be erased by the courts, so it must be resolved into meaning something which it would not commonly be accepted to mean. This Section of the Act was apparently passed to cover ornamental objects which could not receive any protection under Section 4,886, but a careful examination of the weekly issue of patents shows that patents are frequently granted under this design Act for the shape or configuration of manufactures and parts constructed purely for functional purposes. Looking at the subject, however, in the light that the inventor requires all the protection which he can possibly secure, it is probably a wise divergence from the spirit and intention of the Act, though within the letter of the law. The question of identity in design patents is determined by a very materially different method of criticism and investigation from that employed when the identity of functional patents is involved. In the latter class of cases experts trained for the purpose critically analyze the essential features or constructive parts and compare them with each other, noting carefully their operation and object. In the former class, viz.: design patents, the question of identity is determined by the effect on the eye of an ordinary observer, expert comparative testimony is rejected. The question is: Does the alleged new design strike the eye of an average observer as being the same as the design with which it is compared; does the alleged infringing design, in the case of litigation strike the eye of the ordinary observer as the same thing as the design patented?

One of the leading cases, if not *the* leading case, bearing upon design patents is that of Gorham Company *vs.* White (14 Wallace, 511) which contains the views of the Supreme Court of the United States upon the subject, as set forth clearly in an opinion by Mr. Justice Strong. Mr.

Justice Strong, in delivering the opinion of the court, said:

"The Acts of Congress authorizing the granting of patents for designs were plainly intended to give encouragement to the decorative arts, they contemplate not so much utility as appearance, and that, not an abstract impression or picture, but to an aspect given those objects mentioned in the acts. It is a new and original design for a manufacture whether of metal or other material; . . . the law manifestly coutemplates that giving certain new and original appearances to a manufactured article may enhance its saleable value, may enlarge the demand for it, and may be a meritorious service to the public. . . . It is the appearance itself which attracts attention and calls out favor or dislike. It is the appearance itself, therefore, no matter by what genius caused, that constitutes mainly, if not entirely, the contribution to the public which the law deems worthy of recompense. . . . Plainly it must be sameness of appearance (to produce identity) and mere difference of lines in the drawing or sketch, a greater or smaller number of lines, or slight variances in configuration if sufficient to change the effect upon the eye, will not destroy substantial identity."

Mr. Hector T. Fenton, of Philadelphia, in his work on Designs, states (Sec. 15): "The law of combination is equally applicable to designs. As in mechanical devices, a mere aggregation of designs like a mere aggregation of mechanisms do not constitute patentable combinations arising to the dignity of invention. . . . (Sec. 20) Unity of design constitutes another very important question in design cases, and it may be laid down as a general rule that where there is no necessary connection between two designs or parts of a design, there is an absence of unity to render them a single patentable design."

Patents for designs also differ from functional patents in the length of the terms for which they may be granted. Design patents may be granted for the term of three years and six months, or for seven years, or for fourteen years, as the applicant may elect, but he is bound in his application to elect the term for which he desires protection; when the

patent is once issued the term cannot be extended, except by special Act of Congress. All the regulations and provisions which apply to obtaining or protecting patents for inventions, or discoveries, not inconsistent with the expressed provisions for designs apply to patents for designs.

A design is a delineation of form or figure, either plain or solid, a shape or configuration. The construction of an article in accordance with that delineation is the materialization of the conception of the design. Under the decisions in design cases, it has been held that the Act requires that the shape produced shall be the result of industry, effort, genius and expense ; and also requires that the shape, form or configuration, sought to be secured, shall also be new and original, as applied to an article of manufacture.

REISSUE.

It often occurs that a patent through inadvertence, accident or mistake, is defective, and that the inventor's rights thereunder are seriously abridged or threatened. Prior to 1832, no statute existed to correct this defect, but notwithstanding this fact, the Supreme Court of the United States, in an opinion by Chief Justice Marshall, decided that the Secretary of State had a right, where the mistake had been innocently made, to correct the error and reissue the patent. The case in question was that of Grant *vs.* Raymond (6 Peters, 218, 1832).

James Grant, in 1821, had received letters-patents of United States for an improved method of manufacturing hat bodies. He subsequently discovered that his specification was defective, and there being no law provided for reissue, he filed a petition with Hon. Henry Clay, then Secretary of State, praying that his patent be cancelled and a new one issued to him. On the advice of the Attorney-General the reissue was granted and the original patent cancelled.

Grant subsequently brought suit against an infringer to recover damages in the Circuit Court for the Southern District of New York, and obtained a verdict of $3,266.66. The defendant took an appeal to the Supreme Court of the

United States, and there Mr. Daniel Webster, who had been retained by the defendant, argued with all his ability that the Secretary of State had no right or power whatsoever to cancel the original patent and to issue a new one; he contended that our whole system of patents rested upon the statutes, and that no right or prerogative power existed in the President to issue a patent. That eminent jurist, Chief Justice Marshall, however decided that although the right of the Secretary of State to reissue was not altogether free from doubt, yet, if by an innocent mistake, the instrument introduced to secure this privilege fails in its object, the public ought not to avail itself of this mistake and to appropriate the discovery without paying the stipulated consideration. The attempt would be disreputable in an individual, and a court of equity might interpose to restrain him.

The first reissue act was passed in 1832, and between it and the date of the present Act providing for the reissue of a patent, several Acts have been passed, only slightly dissimilar in language from the present Act. Section 4916 of the Revised Statues, reads as follows:

"Whenever any patent is inoperative or invalid, by reason of a defective or insufficient specification, or by reason of the patentee claiming as his own invention or discovery more than he had a right to claim as new, if the error has arisen by inadvertence, accident or mistake, and without any fraudulent or deceptive intention, the Commissioner shall, on the surrender of such patent and the payment of the duty required by law, cause a new patent for the same invention, and in accordance with the corrected specification, to be issued."

No new matter can be introduced into the specification; where no model or drawing has been filed, amendments may be made upon satisfactory proof to the Commissioner that such new matter was a part of the original invention and was omitted by inadvertence, accident or mistake. In case of suit the new patent shall have the same effect and operation as if it had been originally filed in its corrected form.

Sometimes the defect consists in the fact that the appli-

cant claims too much, and desires to incorporate a more limited claim—sometimes he has not claimed as much as the description in his specification would warrant—sometimes the invention is defectively described.

Unreasonable delay in applying for the reissue will operate as a bar against the patentee. What is a reasonable delay? was thoroughly discussed and decided in the now celebrated case of Miller *vs.* The Brass Company (104 U. S., 352, 1881).

The doctrine here laid down is substantially that the right to obtain a broadened reissue is lost after the lapse of a long period of time between the date of the original patent and the date of filing the application for reissue, the length of time which will operate as a bar is not set down as an invariable rule. This same question was involved in numerous cases such as Johnson *vs.* Railroad Company (105 U. S. 539, 1881) Combined Patents Con. Co. *vs.* Lloyd, (11 Fed. Rep. 149, 1882) Sheriff *vs.* Fulton (11 Fed. Rep. 137. 1882). The subject of "Reissue" in all its branches and ramifications is a broad one, and is another division which cannot herein be more than cursorily treated.

DISCLAIMER.

Where a patentee has claimed more than that of which he was the original inventor or discoverer, if the part is material or substantial, and the thing occurred through inadvertence, accident or mistake, and without any fraudulent or deceptive intention, he may file a disclaimer of such parts of the thing patented as he shall not choose to hold, and his patent shall be valid for all that part which is justly his own (Sec. 4917, of the Revised Statutes).

ASSIGNMENT.

If no provision were made whereby a patentee could sell his patent, or grant licenses thereunder, his patent would be of but little value to him, if he did not desire to enter into the manufacturing business himself. Provision is made to protect both the assignor and assignee of a patent, though the law in this regard is not what it should be. Sec. 4898 provides that every patent or any interest therein

shall be assignable in law by an instrument in writing, and a grant may be made to the whole or any specified part of the United States, but the time allotted for the recording of the instrument is too long—it allows three months for record. One month would be ample. Great hardship and loss are liable to occur to the assignee under the existing laws; as an illustration.

A executes an assignment to B for which, at the date of delivery of the deed, B pays A $5,000. B has previously made a title search and has found no assignment of record; within three months from the date of the deed to B, C records an assignment from A for the same patent but executed and delivered prior to the date of the deed to B. A is financially irresponsible, and B is out of pocket $5,000. C has the title to the patent. Of course by withholding the cash consideration and the holding of the deed in escrow, etc., B may make himself safe, but settlement and its incidents are postponed, as well as vexatious delay and perhaps loss occasioned, Ample time for a deed of assignment to arrive from, say, abroad, ought to be allowed; one month would cover all possible requirements for sufficient time.

The law does not provide for the record of licenses, and consequently, record is held not to be constructive notice. This certainly should be provided for, Practically the only remedy which a licensee has for money paid for an alleged exclusive license in territory previously allotted is against the licensor—perhaps irresponsible—when, too late, he finds that the licensor had previously granted the same territorial rights to another—and perhaps after the second licensee has erected a large plant, and spent considerable sums of money for machinery.

Whenever the sole owner of a patent grants to another an undivided interest in his letters-patent the parties hold as tenants in common. Neither is obliged to account to the other for profits or royalties received—unless a special contract exists for the purpose—which makes its own law. This is frequently provided for in the assignment or by special contract.

Each may sell his rights, or assign his interests, without the consent of the other parties in interest. Many very nice questions of law have arisen upon the question of assignment, license and grant, and, in numerous recent cases, fine hair-splitting distinctions have been elaborately discussed in the decisions, especially in cases where instruments purporting to be assignments were contended not to be such, but mere licenses for lack of proper phraseology, and, in numerous cases, have been so held.

Time forbids further discussion of the subject, and deeper invasions upon your indulgence in the consideration of the "Law of Invention." If these brief papers should be the means of giving the layman some insight into this particular branch of jurisprudence the object of their author has been accomplished.

ENGINEERING PRACTICE AND EDUCATION.

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[*Continued from vol. cxxxviii, p. 478.*]

The foregoing shows that the engineer who has to perform responsible work must not trust to guesswork, but must know the principles by means of which to determine the stresses in all parts of the machine or structure, and make his calculations in accordance with these principles. He should know the character of the experiments from which are deduced the constants he proposes to use, and he should also know enough about the tests to have an opinion as to whether they were made under such conditions as to render them applicable to the work he has in hand.

Besides this, he must see, by careful inspection and tests, that the materials used are up to standard in quality. He must draw up such specifications as will secure suitable

material, and then he must apply the necessary tests to determine whether it fulfils the specifications.

In order to do this properly he must, of course, know what tests structural material of suitable quality can be reasonably expected to fulfil, and what kinds of tests are necessary in order to be able to determine whether the material possesses the good qualities desired, and whether it is free from defects.

In order to know what conditions to insist upon as to tensile strength, ductility, capability of bending, etc., he must become familiar with the behavior of the materials under stress and strain, and hence he needs to make a careful study of the experiments that have been performed especially those made under such conditions as occur in practice.

In addition to this he must know what constitutes good workmanship, and he must take the precautions necessary to secure it. Unless these details are faithfully attended to, the result will not be what it should, even though his calculation of the stresses may have been all right, and his constants correct for good materials and workmanship.

In view of what I have said, one might be inclined to ask why disasters are not of more frequent occurrence, and why our structures and machines generally are as safe as they are.

First of all, we may observe that, once in a while, some disaster happens which cannot be prevented from attracting public attention; such as the breakage of the Bussey bridge, or the bursting of the Amoskeag fly-wheel; but, frequently when breakages happen it is not considered by the management to be conducive to their best interests to publish an account of them.

Then there are cases where prospective failure makes itself evident beforehand; in other words, the piece gives warning of structural weakness, and, before an accident happens, it is either replaced by a stronger one or else it is reinforced in some way. Naturally, such cases as these are not published and are known to but a few; for the management would not consider it to be to the advantage of their firm to have the report spread among their employés

or the outside public that the structural weakness existed. Cases of this kind have come to my notice.

Again, there are other cases where the structure or machine is not on the verge of collapse, but where the margin of safety is less than good engineering requires, and where the structural weakness shows itself in a lack of stiffness, and consequently in poor work, in the case of a machine; or in vibration or yielding in the case of a structure, as a building, or a bridge.

We must remember that the strength of a structure is the strength of its weakest part, and that adding to the strength of other parts is only a waste of material; also that adding material where it does not increase the strength is also a waste of material; so that a design which does not properly consider the necessary strength and stiffness of all the parts is not merely unsafe but is also uneconomical, and results in a waste of money.

Enough has been said to show the importance to the engineer of a thorough knowledge of the strength of materials whenever it comes into play in the design and construction of either structures or machines, and it only remains to show that these are matters that the engineer has to consider and act upon at every turn, whether he is what is commonly called a civil engineer, a mechanical engineer, a mining engineer, a metallurgical engineer or a chemical engineer. To be convinced of this, we need only consider the character of some of the duties that devolve upon the engineer, in the different kinds of works which were described in the first three lectures.

Referring next to some other matters in connection with applied mechanics, I must emphasize the importance of taking the greatest care that when the young man is studying the action of the stresses in a beam bearing a transverse load, he should understand what are the assumptions, upon which the theory is based, and also all parts of the theory. Otherwise, he is liable to be led into all sorts of erroneous conclusions. As an illustration, I may say that in my laboratory of applied mechanics, where, of course, the students are required to perform a

variety of tests of the strength and stiffness of iron, steel, wood, cement, etc., we are constantly testing the strength of full-size timber beams. Every once in a while one will break by shearing along the neutral axis or center of the depth, instead of tearing at the bottom or crushing at the top. I remember, on a certain occasion, when I called attention to this fact, that a gentleman proceeded to argue from it that there was a shearing force acting in the case of a beam which the common theory of beams did not take into account. Evidently to him the common theory of beams was only the set of formulæ most commonly recorded in the books, for he apparently was not aware that it does include a consideration of the shearing stresses.

Another illustration might be taken in the fact that the ordinary formulæ for the deflections of beams are deduced from an approximate equation, where one term has been neglected, which is small in all ordinary cases of beams in structures. By using this approximate equation in a case where the neglected term was very large, some one made out an imagined mathematical demonstration that an unbalanced rotating body going at a high speed pounds towards the light instead of the heavy side, a result manifestly absurd.

Again, if the student clearly understands all the assumptions made in deducing the formulæ, he will understand that the Gordon formula for columns is not demonstrated, depending as it does on assumptions that cannot be proved; and he will be in a more judicial frame of mind in trying to determine how to make use of the experimental knowledge on the subject that we possess up to date. Next, in regard to the theory of elasticity; this is necessary in considering certain cases of complicated stresses, and while we use it now to some extent, as in determining the strength of flat plates and of shafting, it will, I do not doubt, come more into use when we get more light experimentally on some matters connected with it. I need say nothing upon the importance of having a knowledge of the principles of friction and lubrication, and of the experimental knowledge on the subject up to date,

beyond calling to your notice that the change from a poor to a good lubricant may often make a decided difference in the size of the dividends received by the stockholders of a large concern.

The next course to receive our attention is that of Thermodynamics and Steam Engineering. It might be assumed by some that this was peculiarly the province of the so-called mechanical engineer; but if you will consider again the account of the different works of which the first three lectures treated, you will realize that, in every work of any magnitude, power is needed, and in almost all cases the power used is steam. The exceptions are those cases where the works are favorably situated for the use of water-power, and even then steam is almost always used in addition; and perhaps I ought to make another exception in the case of sailing vessels, where the wind is used. Other sources of power, or water or wind in cases other than those mentioned, are only employed for small amounts of power.

Without power all the works would have to shut down; the bridge works could not build bridges, the machine shop or manufactory or mill would have to stop, the mine could not be operated, the rolling mill could not run, the dynamos and electric motors would be idle, the paper mill, the sugar refinery, etc., would have to discontinue operations. Moreover, the expenses for power in any large concern form a very large item; they include the first cost of machinery, of necessary buildings, of coal bunkers, etc., the expenses of maintenance, including coal, water and attendance, and the expenses for repairs. It behooves the engineer, therefore, to try to realize the greatest possible economy. One of the largest items of expense, after the plant is once in operation, is coal, and any method by which he can save coal will increase the profits of the concern.

In order to accomplish this, the engineer must understand the principles of steam engineering, and the larger the works with which he is connected, and hence, the greater the quantity of money involved, the more important is it that he should have all the light possible, both from theory and from experiment, that will aid him in determining how

his engines should be designed and built, how his boilers should be designed and built, what degree of efficiency he has reason to expect with any given arrangement which he may propose to adopt. Hence, it is plain that our prospective engineer needs a thorough course in steam engineering, of which thermodynamics is merely the theoretical part; and he needs this, whatever be the kind of engineering works he may expect to be connected with, if they are to be of considerable magnitude. In deciding upon the question as to how such a course should be laid out, we shall assume that he is already familiar with valve gears, and with the rest of the mechanism of the steam engine; also assume that he has had a course on heat in his physics, and that, in this course, he has been taught the subjects of thermometry, calorimetry, and the laws of the transference of heat.

He should be taught the nature and construction of the steam engine indicator; how it is to be used; how the indicator card is taken, and what it means, and he should acquire some familiarity with interpreting the characteristic and also some of the peculiar features of indicator cards; and then he should be made familiar with the general characteristics, *i. e.*, outward characteristics, of the different types of steam engines.

Next, he should receive a thorough drill in the principles of thermodynamics. What is thermodynamics, and what kind of a course should our prospective engineer have in the subject? Thermo-dynamics is simply the mechanical theory of heat, or, in other words, the science of heat with special reference to producing motion and power.

The subject was originally developed from the standpoint of the mathematical physicist, and we have a number of treatises written from this point of view, such as that of Clausius and others. Besides the fundamental principles of the science, they take up elaborate discussions of the nature of heat, and also a large mass of applications and developments in the direction, and from the point of view, of pure science, rather than in the direction of what we need to use in the consideration and the study of the

action of the steam engine, or of other heat engines, as the gas engine, the hot air engine, etc.

Instead of this, in the course to be given to our prospective engineer, we should include a thorough treatment of the fundamental principles of the subject, a study of the laws of thermo-dynamics, Carnot's function, and the whole set of fundamental equations, and their interpretations. Then should come the applications of these fundamental principles to the gases and vapors used in practice for producing power, especially steam, and also gas and air. Then a study of the experiments that have been made, and the results of the experiments on the properties of vapors and gases; the experimental determinations of the mechanical equivalent of heat; the tables of the properties of saturated steam, as pressure, temperature, density, specific heat, latent heat, entropy, etc.; also the same for other vapors. Then a study of the laws governing the flow of fluids, both gases and vapors, through orifices and in pipes, including a consideration of the resistances and a study of the steam injector.

Then the student is prepared for a study of the behavior of steam in the cylinder of a steam engine. At this point he should be taught the modern methods of analyzing and separating the various actions of the steam that passes through the engine, and of giving to each its proper consideration; as, for example, the heat used up in work, that used up in cylinder condensation, that used up in condensation in the jackets, if there are any, the heat rejected by the engine, radiation; also the methods of studying the effects of superheated steam, etc.; all these for both single and multiple expansion engines, and, in the cases of the latter, the effects of different sizes and arrangements of receivers, the methods of proportioning the cylinders, etc.

Next, he should learn what are the requirements for a proper engine test, both when it is made for ordinary commercial purposes, and also when it is to be made in a thoroughly complete and scientific manner for the purpose of obtaining definite knowledge as to how to produce the

best and most economical results by means of a steam engine.

The day when the taking of a few indicator cards from an engine, or the making of tests in which scientific principles and scientific accuracy are neglected, and claiming that such tests can furnish information as to what the real effects of different arrangements are, is rapidly passing away, the advocates of such a course confounding themselves and each other by reaching too many contradictory conclusions by their tests.

Now, from the experimental point of view, the student should have presented to him, in a carefully systematized form, an account of such experiments as have been made, with such a degree of accuracy and such regard for scientific principles as to render them worthy of study. Of course, there will be a number of tests in this list which are not up to the scientific standards of to-day; but such a study will make the student familiar with what is the extent of our knowledge of the subject up to date, and he will be all the better able to make this study effective, by being relieved of the necessity of reading accounts of a lot of worthless tests for the sake of finding out those that are worth considering.

Then he should have a good course on steam boilers, including the construction and action of the various types in use; on the laws controlling the combustion of fuel, and the evaporation of water; on questions of heating surface, grate area, tube section, horse-power, capacity, evaporative efficiency, evaporation from and at 212°, priming or superheating, draught, quantity of air required for combustion, temperature of flue gases, size of chimney, methods of feeding, methods of determining quality of the steam; and on boiler accessories, such as gauges, water glasses, grates, stokers, feed pumps, injectors, feed water heaters, economizers, damper regulators, etc. This instruction should embrace also the requirements for a reliable and accurate evaporative test; what are the possible maximum evaporative efficiencies, and what are usual evaporative efficiencies attainable under ordinary conditions.

He should also study the more recent applications of thermo-dynamics, such as air compressors, gas engines and refrigerating machines. In these cases a lack of familiarity with the laws of thermo-dynamics on the part of the makers is very likely to make itself apparent to the user through the medium of his pocket-book, and in no case will this be more likely to be true than in the case of the refrigerating machine, either for cold storage or for the making of artificial ice, and those who are engaged in this business are very rapidly realizing this fact.

Now, when the student has finished the work referred to on the steam engine indicator, and has acquired the fundamental principles of therm-odynamics, and is studying the action of the steam in an engine, it is a proper time for him to begin work in the laboratory, by making steam engine tests, alternating his duties at each successive test until he has been drilled in performing all the different parts of the work, and in making all the necessary calculations. For this purpose a small engine is, of course, better than none, but it is much better for the education of the student if his work can be done upon an engine sufficiently large to work with an economy comparable with that found in such engines as are used in large and well-designed modern plants. Such tests made by the student himself, under the direction and guidance of the instructor, will leave a lasting impression upon his mind, and will convey information which he cannot acquire as well in any other way. Hence, it is far better to use a triple, or at least a compound engine, of sufficient size to secure a steam consumption of about fourteen or fifteen pounds of water per horse-power per hour, than to use a small single engine, where the steam consumption per horse-power per hour is as high as thirty, forty or more pounds. In making the tests no loose work should be allowed, but the student should be required to perform all the work with the greatest accuracy possible, and this accuracy should be such as to render the test thoroughly reliable from a scientific standpoint. This can be accomplished provided the instructor exercises the necessary supervision over the work.

Later in the course the student should make accurate and carefully conducted boiler tests on some large boilers. By these methods, he will be made to appreciate better the work which he is doing in the class-room and will see that it finds its application in just such work as an engineer has to do in the course of his profession. Of course, he should have to perform other sorts of experimental work with steam in the laboratory besides engine and boiler tests, but of these will be referred to later.

The whole idea of such a course as I have outlined is, as you will see, to give the student a thorough drill in the fundamental principles of the subject, and then to teach him how these principles apply to the work of the engineer, by means of both class-room and laboratory work, the deductions and developments from the fundamental principles being made in the direction of engineering work, instead of in the direction of pure science; and then, by means of this work, and also by showing him where we stand to-day in regard to the matter of reliable experimental results, to equip him as fully as possible to appreciate and to take part in the best and most scientific engineering work of the present times, and thus to be ready in the future, ever to take advantage of, and to take his part in developing, whatever progress the future may have in store for us.

Another fundamental subject is hydraulics. Our prospective engineer should understand the principles of hydrostatics and hydrodynamics; in other words, the laws governing the pressure of water, and the flow of water, whether in pipes, in open channels, through orifices or over weirs. He should also be familiar with the character and the results of such experiments as have been made upon these subjects, and should know how to conduct such experimental work.

Whatever may be the special line of engineering in which he is engaged, he is liable to have to establish a water supply, with all the necessary works, such as reservoirs, pumping engines, piping, etc.; or to build a system of sewerage, or he may find his manufactory so situated that it is advisable to take advantage of a water-power, and to

build all the necessary works, such as dams, canals, locks, sluice-ways, etc. He may have to establish river or harbor works, or, even if not these, he may have to build a wharf, a quay, or even a dock, if his works are on the water's edge. Unless he is to make a specialty of hydraulic work, he cannot, in a four years' course of engineering, afford the time to make himself master of the details of all these kinds of works, but he should become familiar with the principles stated above, and then he can afterward make a special study of part or all of these subjects.

Next comes the question as to how far electricity should be accounted a fundamental subject, and consequently one to be required of all engineering students, whatever their special lines.

It is now usually customary to require them to learn some electricity in connection with general physics, and sometimes a little more; the rest being given to students of electrical engineering only.

Whether or not a considerably larger amount should be put in the list of fundamental studies, will depend upon how far and how intimately electrical appliances come to associate themselves with the every-day work of the engineer, whatever his specialty. The probabilities are, it seems to me, that it will not be many years before we shall have to insert a much larger amount of electricity than we now do in our list of fundamental studies.

The subjects thus far enumerated are fundamental, and are necessary for our prospective engineer, whatever be the special line of engineering to which he is to devote himself. He cannot afford to do without any one of them.

In laying out, therefore, any engineering course, of whatever name, whether civil, mechanical, mining, metallurgical, electrical, or chemical engineering, we should arrange, first of all, the time necessary to give good courses in mathematics, general physics, drawing (including descriptive geometry), mechanism, applied mechanics (including, of course, strength of materials), thermo-dynamics and steam, and the general principles of hydraulics. Moreover, thorough instruction in these should not be sacrificed to any

other subjects, whether of an engineering or of a general character. In other words, the work in these subjects should be thoroughly performed, whatever else is or is not accomplished.

When this has been done, we can then, and not till then, begin to consider what other subjects should be added, and these may be classified as follows: (1) subjects of a professional nature bearing on the work of an engineer in general, whatever his specialty; (2) subjects of a professional nature, which bear directly on the special line of engineering which the course is intended to teach; (3) subjects of a non-professional character intended to broaden the field of knowledge and to impart general information; (4) subjects which fulfil partly one of these functions, and partly another.

In the first class, though respectively of very different degrees of importance, I should place (*a*) machine design, (*b*) dynamics of machinery, (*c*) metallurgy of iron, (*d*) heating and ventilation, (*e*) stereotomy, (*f*) surveying, (*g*) shop-work. How many, and which of these subjects can be added will depend upon circumstances.

Reviewing in detail the kind, of course, I have in mind under each of these heads, I will make the following remarks:

(*a*) *Machine Design.*—This course, to be of the greatest value, should take up problems of real engineering design, and should deal especially with the details. Thus the student should be made to study each separate piece, and its connection with the other pieces, to determine the forces acting upon it, and the stresses to which the piece is subject in consequence of the action of these forces, and to design the separate details in such a manner that they shall have the requisite strength and stiffness.

Of course, it is desirable, also, to have some work done on mechanism design, where the student shall have practice in adapting mechanisms to the special objects that are to be accomplished, but it is also important that he should learn that in making any such design, he must study the strength and stiffness of each separate piece of which the machine is

composed, and must be fully impressed with the facts that any one of these that is not properly designed, means a machine that is not properly constructed and may mean the total failure of the resulting mechanism.

(*b*) Under the term dynamics of machinery, I include such subjects as governors, fly-wheels, dynamometers, the action of the reciprocating parts of a steam engine, etc. I need only mention these topics to make plain their importance to any engineer.

Metallurgy of iron and heating and ventilation will, I think, also make plain their importance by a mere mention of their names.

[*To be concluded.*]

A REVIEW OF STEREO-CHEMISTRY.*

BY STEWART WOODFORD YOUNG.

The old structural formula for methane represented the molecule of that substance as being constructed by placing the carbon atom at the point of intersection of the two diagonals of a square, the four corners of the square being the positions occupied by the four hydrogens. This formula (*Fig. 1*) however, conflicts with the facts when we consider the di-derivatives of methane. As is well known,

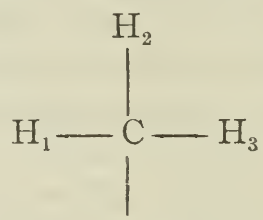


FIG. 1.

methane allows of the formation of but one series of di-derivatives. One and only one dichlormethane is known. Now, this formula allows of the existence of two series of isomeric di-derivatives, (*Fig. 2*) (*a*) representing a di-deriva-

* Read before the Chemical Section.

$$\begin{array}{ccc} & R & \\ & | & \\ H— & C & —R \\ & | & \\ & H & \end{array} \qquad\qquad \begin{array}{ccc} & R & \\ & | & \\ H— & C & —H \\ & | & \\ & R & \end{array}$$

(*a*) (*b*)

FIG. 2.

tive, in which the two substituting radicals are "neighboring," and (*b*) representing a di-derivative in which the two radicals are "opposite." A little study will show that the fact that but one series of di-derivatives is formed, cannot be explained by any plane formula We must, therefore, seek for our formula a special representation.

As early as 1860, Pasteur suggested that the property of optical activity (see later) possessed by tartaric acid might be explained if we considered the atoms composing the tartaric acid molecule as arranged in the form of a helix. Since this, many suggestions as to special formulæ have been made, but not until 1874, was there published any exhaustive treatise on the subject.

In this year Van't Hoff, and independently of him, Le Bel suggested the tetrahedron formula for methane. This formula represents the four hydrogens of methane as occupying the four apices of a tetrahedron, while the carbon occupies a position in the centre of the tetrahedron (*Fig. 3*). It is evident from a study of this formula that it permits of but one di-derivative.

A most interesting application of this formula is found in the explanation, by means of it, of that previously unaccountable phenomenon, optical isomerism. Many chemical compounds, when in solution or in fusion have the property of causing the plane of a plane-polarized ray of light to be rotated when passed through the solution or fused mass. Le Bel and Van't Hoff noticed that all such substances could be considered as derivatives of methane, in which each of the four valences was saturated by a different radical. A carbon atom possessing such properties was named "asymmetric," and Van't Hoff considered optical rotation to be conditioned by the presence of such an asymmetric carbon atom. He afterward concluded that every

such asymmetric carbon atom showed optical activity. There are some apparent exceptions to this latter statement, but all are easily explainable.

Now, rotatory polarization is found to exist in two forms. Some bodies rotate a polarized ray to the right and some to the left. Such bodies are called, respectively, dextro-rotatory and lævo-rotatory. It is found that, in a great many cases, if we have a certain compound which is dextro-rotatory, there is a lævo-rotatory compound which, in all other repects, is identical with the dextro compound. To explain the existence of dextro- and lævo-isomers, let us refer back to our formula (*Fig. 3*). If we consider H_1, H_2, H_3 and H_4 to be different radicals, it will be seen that on exchanging the position of any two of them, the formula will no longer be identical, but the one will appear as the image of the other, as it would be seen in a mirror. This affords a simple and plausible explanation of dextro- and lævo-isomers.

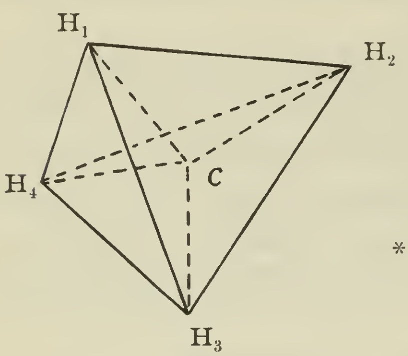
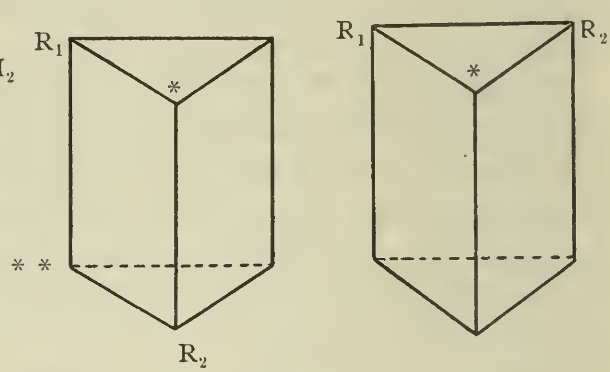


FIG. 3.



(1) FIG. 4. (2)

Deductions have been made as to the validity of the Ladenburg and Kekulé formulæ on the ground of optical activity. It has been pointed out that in the Ladenburg formula an ortho-di-derivative, in which the two substituting groups are different, will call for an asymmetric carbon atom (marked * in the *Fig. 4*, No. 1). But we should not expect optical activity here, it seems to me, because the carbon atom marked * * in *Fig. 4*, No. 1, is also asymmetric, but in a sense opposite to the first one. Therefore, their rotations should neutralize each other. In the case of the meta-derivative, however, there appears to be an asymmetric carbon, and only one. Therefore, we should expect such a

compound to be active, but as it is not, it stands, at present, as an argument against the prism formula for benzene.

Respecting the primal cause of rotation but little is positively known, although several explanations are offered.

The credit for the theory as above stated is due to Le Bel and Van't Hoff. Van't Hoff appears to have preceded Le Bel by a few months, but Le Bel's considerations were arrived at entirely independently. Since the first announcement, Le Bel seems to have been somewhat more active in elaborating the theory in its details.

We are now in a position to explain some apparent exceptions to the statement that every asymmetric carbon atom is optically active. (1) Racemic acid, which is isomeric with tartaric acid, contains two asymmetric carbon atoms (COOH, OH, H, $C_a - C_b$, H, OH, COOH), *a* and *b*, but racemic acid is inactive. However, Pasteur proved that racemic acid consists of equal molecules of dextro- and lævo-tartaric acids. Such being the case, the two equal and opposite rotations would neutralize each other and the mixture would be inactive. (2) Mesotartaric, which also contains two asymmetric carbon atoms is inactive. The inactivity of this substance is explained as being due to the fact that of the two asymmetric carbon atoms one is dextro and the other lævo. Consequently, the two neutralize each other. Letting "r" represent a dextro rotatory group and "l" a lævo rotatory group, we then have the following possible conditions for the tartartic acid isomers;

$$\begin{array}{c} r \\ | \\ r \end{array} \qquad \begin{array}{c} l \\ | \\ l \end{array} \qquad \left[\begin{array}{ccc} r & & l \\ | & + & | \\ r & & l \end{array}\right] \qquad \begin{array}{c} r \\ | \\ l \end{array}$$

dextro-tartaric acid.	lævo-tartaric acid.	racemic acid (inactive,)	mesotartaric acid (inactive).

It is found that, in general, asymmetric compounds which depend for their asymmetry on the presence of one or more halogens directly connected to the nuclear carbon, are inactive. Two explanations for this irregularity are are offered: (a) Victor Meyer suggests that the great vibratory activity of the halogen causes it to assume alternately positions corresponding to both the dextro- and lævo-isom-

ers; (b) Easterfield's investigations on mandelic acid seem to show that the formation of asymmetric halogen compounds is accompanied by an "umlagerung" in one-half the molecules, so that the resultant product contains equal molecules of the dextro and lævo isomers.

We will now pass on to some supplementary theories, derived from that of the tetrahedron formula for methane.

Wislicenus' theories of relative rotation and favored configuration in ethane derivatives.

This theory is based upon a dynamical conception of the ethane molecules. If we consider a pair of singly-linked carbon tetrahedra we will have the condition represented in *Fig. 5*.

(In the following considerations the term "corresponding positions" is to be taken as meaning position directly under or over one another, *e. g.*, in *Fig. 5*, a and a' would be corresponding positions when a' was directly under a; or, in other words, when a line connecting a and a' was parallel to the conjoined axes of the two tetrahedra. The line connecting the two singly-linked carbon atoms, or, in other words, the line representing the direction of the two carbon valences which are used in linking the two nuclear carbon atoms, is called the axis of rotation of the molecules).

Now, Wislicenus considers that on the application of heat to a molecule of any ethane derivative, there is induced in that molecule a relative rotation of the two tetrahedra about the axis of rotation. As to Wislicenus' idea of favored configurations, it is very simply explained.

Wislicenus assumes that between like groups there exists a mutual repulsion, the degree of that repulsion depending on the degree of negativity of those groups. Assuming, now, the introduction of a negative group in each of the tetrahedra in *Fig. 5*, it will be apparent that, if such repulsion as Wislicenus describes, does actually exist, and if such possibility of rotation, as he assumes, also exists, there will be formed a configuration of the disubstituted molecule, in which the two negative groups are opposite each other, *i. e.*, as far from each other as they can get. If b and c', in *Fig. 5*, be two negative groups, then *Fig. 5* repre-

sents the favored configuration for such a molecule. It is further apparent that the application of heat to such a mole-

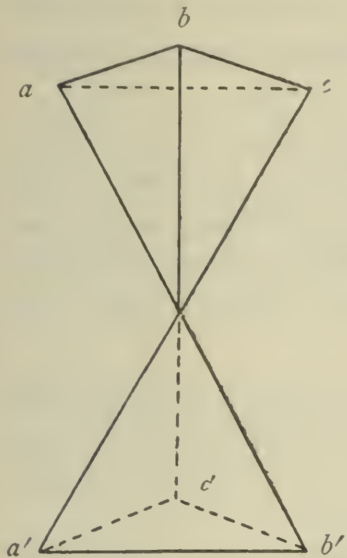


FIG. 5.

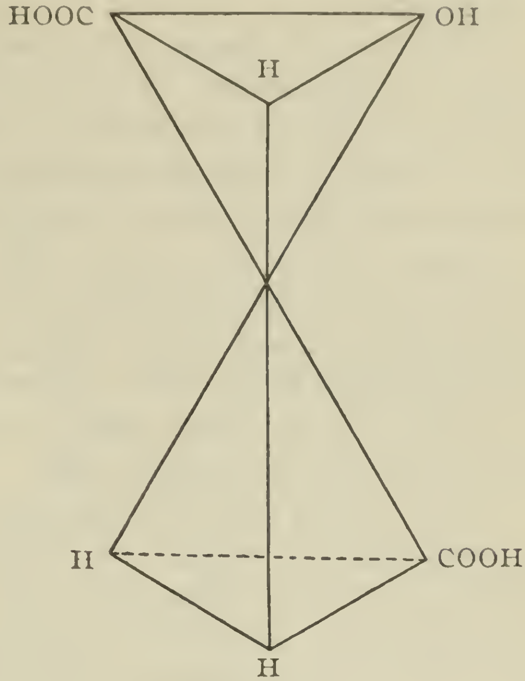


FIG. 6.

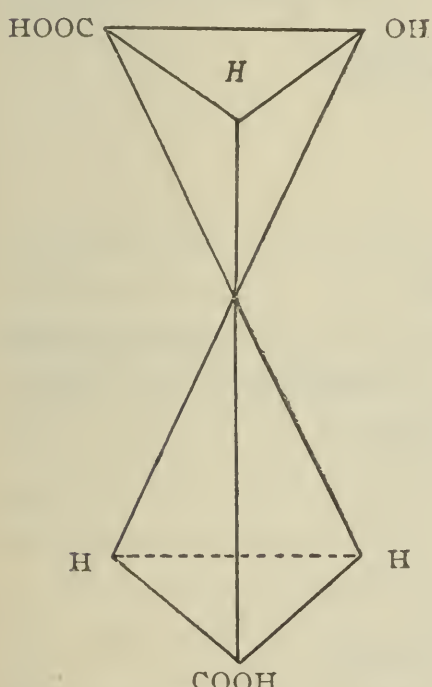


FIG. 7.

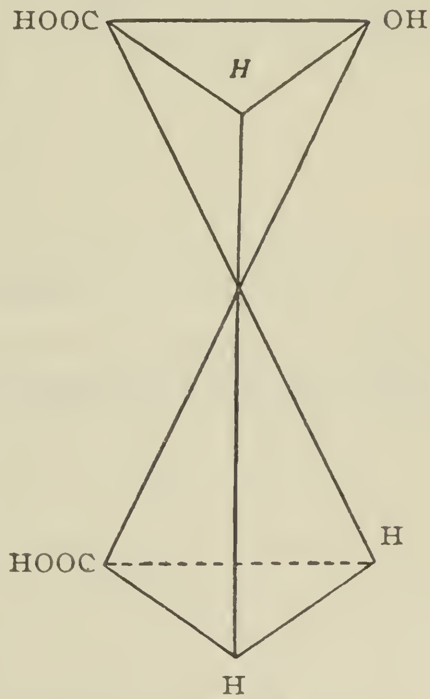


FIG. 8.

cule may overcome the directive tendencies of the two negative groups, and continuous rotation may result. On again

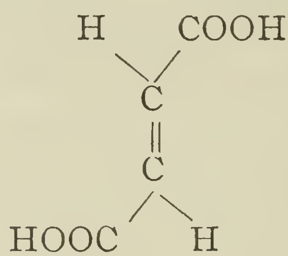
cooling to a point at which the directive tendencies preponderate, the molecule would again assume its favored configuration.

Wislicenus' reasons for assuming the existence of favored configurations and of relative rotation are best illustrated by the transformation of certain ethane derivatives into ethylene derivatives, and of certain ethylene derivatives into other ethylene derivatives.

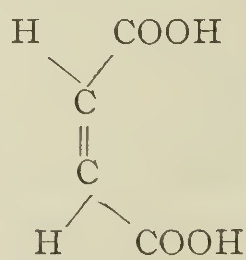
Malic acid (*Fig. 6*) has two configurations in which hydrogen and hydroxyl are in corresponding positions, and, consequently, capable of losing water and being converted into ethylene derivatives. Now, of these two configurations one (*Fig. 7*), on losing water, would give fumaric acid, and the other (*Fig. 8*), maleic acid.

In the third possible configuration for malic acid (which is represented in *Fig. 6*), hydrogen and hydroxyl do not occupy corresponding positions, and the molecule would not split off water while in that position.

It is evident that the acid from configuration shown in *Fig. 7* would be an acid with the carboxyls on opposite sides, viz.: fumaric:



while the configuration represented in *Fig. 8* would yield an acid with the two carboxyls on the same side, viz.: maleic.



Now, at the comparatively low temperature of 150°, the favored configuration of malic acid exists apparently alone, for we get, by the splitting off of water at that temperature,

fumaric acid. This would be expected from the favored configuration, which is *Fig. 7* (simply imagine the OH and its corresponding H to have split off and the two tetrahedra to have folded together until the two points previously occupied by H and OH came into contact. We would then have the doubly linked tetrahedra, and the two COOH groups would be on opposite sides of the molecule (*Fig. 9*).

By producing the anhydride of malic acid and heating this, we get maleic acid. Now, in order to form the anhydride, rotation must take place until the two carboxyls are in corresponding positions. An anhydride of this nature on losing water would yield maleic acid. The configuration

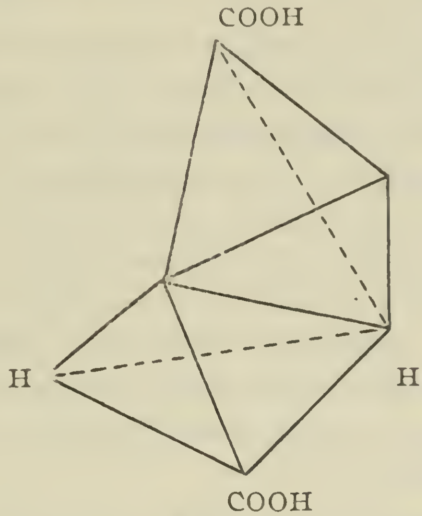


FIG. 9.

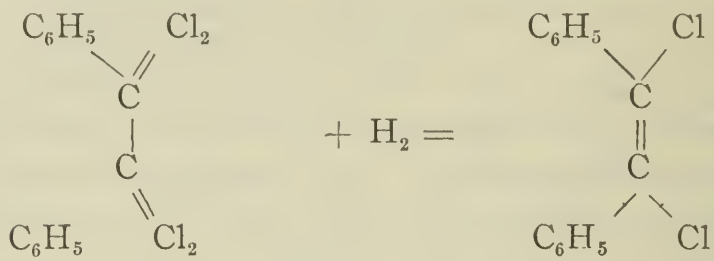
of the maleic acid essential to yielding an anhydride is represented in *Fig. 8*. It is evident that this configuration must yield maleic acid.

Further, brom-succinic acid on treatment with alcoholic potash, yields fumaric acid. Now, the favored configuration of brom-succinic acid is similar to that of malic acid, and on removal of HBr the same unsaturated isomer is formed, as by loss of water from the favored configuration of malic acid.

The easy transformation of maleic acid into fumaric acid has been explained by assuming that an addition product is first formed (brom- or chlor-succinic acid). This, then, allows of rotation to the favored configuration, where it again loses HBr and is converted, not back into maleic, but rather into fumaric acid. Many other transformations among ethylene

derivatives are most readily explained on the basis of Wislicenus' assumptions; one in particular is of interest. Tolane tetrachloride yields on reduction two dichlorides, which are isomeric and bear to one another the same relations that are found in fumaric and maleic acids.

The transformation is represented in the equation;



From a study of the three configurations of the tetrachloride, it will be found that in each there are contained chlorine atoms in corresponding positions. It will be further found that, of the three configurations, two can yield the stable dichloride and one the unstable. Accordingly, Eiloart has found that at higher temperatures, when all three configurations can exist, on account of rotation, about two-thirds of the yield was stable and one-third unstable. At lower temperatures less than one-third of the unstable dichloride was produced on account of the preponderance of directive tendencies.

THE RELATIVE STABILITY OF METHYLENE RINGS.

Two theories have been advanced to explain the increase of stability that is noticed in methylene rings, when the number of methylene groups increases. The first is v. Baeyer's so called "strain theory." V. Baeyer considers that in doubly and trebly linked carbon compounds there are respectively two and three valences that are "strained" from their normal or ethane condition, and that on account of their strained condition they render the linking very liable to rupture. Thus ethylene derivatives are unstable, and acetylene derivatives in many cases even explosive.

In applying this thought to methylene rings it is found that although only single linkings are present, nevertheless these single linkings must be considered as diverted from their normal direction. Von Baeyer calculates this diver-

gence for trimethylene rings to be 24° 44′. In tetramethylene rings it is 9° 34′, in pentamethylene rings it is 0°44′, and in hexamethylene rings it is—5°76′. It is universally conceded that trimethylene rings are the least stable of any, tetramethylene being second in order of instability. There is some dispute as to the relative stability of penta- and hexamethylene, later investigations seeming to point to pentamethylene as the more stable.

The second of the above-mentioned theories is that due to Wunderlich, who conceived the actual shape of a carbon atom to be a tetrahedron. The points of affinity in these tetrahedra would be in the center of each face, where there is most matter, or, at least, we can consider the resultant of affinity as acting at those points. Consequently, the position of two singly-linked carbon atoms would be face to face. Now, in the formation of methylene rings the two faces of neighboring carbon atoms can no longer touch or be parallel. Since, further, the attraction of any two bodies decreases as the square of the distance, it follows that there will be less attraction as the divergence increases. Thus we arrive at the same conclusion as v. Baeyer as to the relative stability of methylene rings.

Skraup has suggested an explanation of the fact that in the breaking of double bonds, only one of the bonds is broken, and not both. Skraup accepts Wunderlich's hypothesis, and, on the basis thereof, undertakes a consideration of doubly-linked carbon atoms. Two such doubly-linked Wunderlich tetrahedra would have an edge of each in common, and their points of affinity cannot be in contact. Since they are not in contact, Skraup supposes it possible that oscillations causing alternate approach and recession between each pair are possible.

Now, two points of affinity which have separated are less saturated than when nearer together, and addition would take place at those points rather than at the positions occupied by the two points that have approached.

Thus only one bond is broken, whereas both would be affected alike if they were permanently equal. Now, since the two pairs of points *alternately* approach and recede, we

should expect equal numbers of bonds on each side of the molecules to be broken. Consequently, we get equal molecules of dextro- and lævo-tartaric acids from fumaric acid. Eiloart has suggested an objection to this idea, viz.: Since when two affinity-points recede, the attraction decreases, and when two approach, attraction increases, it is difficult to conceive why the condition of the two doubly-linked Wunderlich tetrahedra is not a condition of unstable equilibrium which the slightest displacement would cause to collapse. This objection may, in a measure, be answered by the following considerations: We have to consider, in unsaturated compounds, not only the carbon atoms themselves, but also the groups that are connected with them. Now the oscillatory displacement of two doubly-linked Wunderlich tetrahedra not only increases the attraction of the two carbon atoms, but also, by bringing nearer together the groups connected with them, causes a continual increase of repulsive force between these groups, until a point is reached at which this repulsive force exceeds the attractive force of the two carbon atoms themselves (by virtue of inertia, the two tetrahedra would be carried past the point of equilibrium), and the tetrahedra are forced back through the second phase of their oscillation.

INFLUENCE OF SPACE OCCUPIED ON STABILITY AND ON ORIENTATION OF GROUPS IN THE SUBSTITUTING OF AROMATIC HYDROCARBONS.

Bischoff has suggested that the cause of the instability of carbonic acid may be due to the fact that the two hydroxyls do not have room enough to perform their oscillations without conflicting with one another, and that, conflicting with one another, they split off water and carbonic acid becomes carbon dioxide and water.

$$CO<^{OH}_{OH} = CO_2 + H_2O.$$

He explains the much greater stability of the bicarbonates by assuming a repulsion to exist between OH and ONa which is greater than that between two OH groups.

Consequently, these two could not come near enough to conflict and the compound is stable.

The two formulæ here given represent the relative positions of the groups in H_2CO_3 $HNaCO_3$ and Na_2CO_3

$$\mathrm{CO}<{}^{\mathrm{OH}}_{\mathrm{OH}} \qquad \mathrm{CO}<{}^{\mathrm{ONa}}_{\mathrm{OH}} \qquad \mathrm{CO}<{}^{\mathrm{ONa}}_{\mathrm{ONa}}$$

Bischoff has applied this idea to many organic compounds, and has carried out exhaustive investigations upon the methyl and ethyl succinic, tartaric and glutaric acids.

Taking the succinic acids as an example, the results of Bischoff's work are well illustrated. He found that, considering these compounds as regards their stability against anhydride formation, they could be arranged in a perfectly definite series, as follows (the arrangement being from stable to less stable):

(1) Succinic acid.
(2) Methyl-succinic acid.
(3) Di-methyl-succinic acid.
(4) Tri-methyl-succinic acid.
(5) Tetra-methyl-succinic acid.

That is invariably the introduction of a larger group for hydrogen decreases the stability against anhydride formation; because, as Bischoff puts it, there is less and less room for the oscillation of the two carboxyls, which are brought into conflict more and more readily.

A very interesting case of the influence of space occupied, is that of pyrocinchonic acid, which exists only as an anhydride, whereas its di-ethyl salt is very stable.

If the formula No. 1, following, represents pyrocinchonic acid, Bischoff's conception of the ethereal salt would be represented by No. 2.

$$\begin{array}{lcl} CH_3-C-COOH & \qquad & CH_3-C-COOC_2H_5 \\ \quad\;\; \| & & \quad\;\; \| \\ CH_3-C-COOH & & CH_3-C-COOC_2H_5 \end{array}$$

No. 1. No. 2.

An interesting application of Bischoff's principle of space occupied has been made by Kehrmann, in connection with the orientation of substituting groups in benzene derivatives.

It is a very general statement that a group substituted in any position in benzene, renders the positions neighboring to it more readily liable to substitution. Thus the nitration of phenol gives mostly the ortho product, as would be expected. However, a small quantity of para compound is formed. This, Kehrmann says, is on account of a slight influence felt on account of lack of room about the OH groups. Thus, some of the nitro groups not being allowed to enter in the favored ortho position, are on account of repulsion between OH and NO_2 forced as far away as possible.

In nitrating nitro-benzene to the di-nitro body we get almost exclusively the meta compound. The OH in phenol shows tendencies toward prevention of ortho substitution, which are, however, comparatively slight. In nitro-benzene, on account of the much greater size of the NO_2 group over the OH group (in phenol), almost no ortho substitution is permitted and the nitro groups assume meta-positions (the same as is assumed by them in di-nitration of phenol which gives a 1, 2, 4 compound).

However, very small quantities of ortho and para di-nitro benzenes are produced on nitrating nitro-benzene, the result of the still existant tendencies to ortho substitution, with a small tendency toward para that was observed in the case of nitrating phenol.

The above report was compiled simply in order to present to the members of the Chemical Section, in the time

that could be spared to such a paper in one evening, as clear an idea as practicable of the main points covered by the field of stereo-chemical investigation. The paper is simply a compilation, and, with the exception of one or two suggestions, introduces no original thoughts. The writer hopes to present, later, a report upon the theory of rotatory polarization in fluids, and to suggest some possible explanations of the possible *primæ causæ* thereof.

The writer also wishes to state that he has been greatly aided in this compilation by the excellent articles of Victor Meyer (B. 23, 569, *Ergebnisse und Ziele der Stereochemischen Forschung*), and of A. Eiloart ("Review of Stereochemistry," *Am. Chem. Jour.*, **13**, No. 7, *et. seq.*)

THE RESISTANCE TO CORROSION OF SOME LIGHT ALUMINIUM ALLOYS.*

By JOSEPH W. RICHARDS, PH.D.

It is well known that pure aluminium is a comparatively soft metal, and that for many machanical purposes where strength is a prime consideration, it is strengthened and hardened by being alloyed with a small proportion of some other metal, such as copper, nickel, silver, German-silver, or titanium. While pure aluminium has a tensile strength in castings of 15,000 pounds per square inch, and in sheet of 25,000 pounds, the addition of 5 per cent. of nickel or German-silver, or 2 per cent. of titanium increases the strength to 20,000–30,000 pounds in castings, and 40,000–50,000 pounds in sheet. At the same time as the strength is thus increased from 50 to 100 per cent., the specific gravity is not increased over 5 per cent.; all of these light, strong alloys being lighter than 3. An American firm making aluminium bicycles uses an alloy containing about 8 per cent. of copper and 12 per cent. of zinc, giving them castings of great rigidity.

The object of the tests about to be enumerated was to determine the relative resistance of some of these light

* Read at the stated meeting of the Chemical Section, held December 18, 1894.

alloys to corrosion. The strips of rolled metal were immersed in the following liquids:

(1) *Dilute caustic potash*, 3 per cent.—The behavior of the alloys in this solution shows their relative resistance to alkali, such as in strong soaps, etc., and shows the suitability of the alloys for laundry purposes. Solution cold.

(2) *Dilute hydrochloric acid*, 3 per cent.—This is the only acid which attacks aluminium rapidly. Solution cold.

(3) *Concentrated nitric acid.*—Shows the suitability of the alloys for replacing platinum in the Grove battery. Acid cold.

(4) *Strong acetic acid.*—Shows the resistance of the alloys against vinegar, and bears directly on the uses of the metal for pickling-kettles, etc. Solution at 60° C. = 140° F.

(5) *Strong solution of common salt.*—This shows the resistance to the agent present continually in cooking utensils. It also shows light on the suitability of aluminium for the metal cases in which artificial ice is made, a use for which its great heat conductivity would particularly fit it. Solution at 65° C. = 150° F.

(6) *Solution of carbonic acid gas.*—Aluminium has been suggested for trimmings on soda-water fountains and for the metal cups for holding soda-water glasses. The action of water charged with CO^2 would also correspond to the action of rain-water and in general to exposure out of doors. Solution at 25° C. = 77° F.

TABLE I.

RELATIVE RESISTANCE TO CORROSION. (Pure Al = 100).

	Caustic Potash.	*HCl.*	*HNO^3.*	*NaCl.*	*Acetic Acid.*	*CO^2 Water.*
3 per cent. copper	13·0	10 8	26·2	37	41·2	not corroded
3 per cent. German-silver .	1·4	4·4	9·8	78	26·0	133·3
3 per cent. nickel	5·9	3·2	11·3	31	20·7	30·8
2 per cent. titanium . . .	47·0	133·3	51·9	63	80·5	not corroded
99 per cent. aluminium .	100·0	100·0	100·0	100	100·0	100·0

TABLE II.

ACTUAL LOSSES PER DAY (in milligrams per square centimeter of surface).

	KOH.	*HCl.*	*HNO^3.*	*NaCl.*	*Acetic Acid.*	*CO^2 Water.*
3 per cent. copper	265·0	53·3	36·1	0·1	0·4	0·
3 per cent. German-silver .	1,534·4	130·6	97·7	0·05	0·6	0·01
3 per cent. nickel	580·3	180·0	83·0	0·13	0·75	0·04
2 per cent. titanium	73·4	4·3	18·6	0·06	0·20	0·
99 per cent. aluminium . .	34·6	5·8	9·6	0 04	0·15	0·01

TABLE III.

TIME WHICH WOULD BE REQUIRED BY THE SOLUTION IN EATING THROUGH THE WALLS OF A VESSEL 1 MM. ($\frac{1}{25}$ inch) IN THICKNESS.

	Dilute. KOH. *Days. Hrs.*	*Dilute. HCl.* *Days. Hrs.*	*Conc. HNO^3.* *Days. Hrs.*	*Strong. Acet. Ac.* *Days.*	*Strong. NaCl.* *Days.*	*Saturated CO^2 water.* *Days.*
3 per cent. copper . . .	1— 2	5— 7	7—20	705	2,820	—
3 per cent. German-silver	0— 4	2— 5	2—22	467	5,600	28,000
3 per cent. nickel	0—12	1—13	3— 8	379	2,130	7,000
2 per cent. titanium . .	3—20	64— 0	14—20	1,375	4,550	—
99·9 per cent. aluminium .	7—20	46—22	28— 8	1,810	6,800	27,000

Remarks on the Tables:—For bath-tubs, wash-basins, laundry-tubs, wash-boilers, and any use in which the alloys come in contact with alkali, the pure metal resists corrosion far better than any of the alloys examined. At the same time, if greater strength is required, the copper alloy stands next in suitability, and possesses the advantage of casting with less shrinkage than pure aluminium.

For purposes where free hydrochloric acid may accidentally be encountered, the titanium alloy recommends itself as far superior to the other alloys, and even to the pure metal.

For use in nitric acid, the pure metal stands first, and it would be a fair conclusion that the purer it is the greater will be its resistance. It would, therefore, be preferable to obtain the very purest aluminium for making battery plates, such as the Pittsburgh Reduction Company's 99·9 per cent. quality. A sheet of such metal one-tenth inch in thickness would bear over a month constant immersion in the concentrated acid.

In strong acetic acid the alloys all resist well, but the pure aluminium best. If it is necessary to have considerable strength, the titanium alloy is the best. The use of such alloys for steam-jacketed kettles in pickle and vinegar works; also for evaporating dishes, etc., in chemical works is of rapidly-growing importance.

In strong salt solution, pure aluminium is best, but the German-silver alloy stands highest among the alloys.

Since this alloy is of a fine color, strong and quite elastic, its use would appear advantageous in cooking utensils, but especially for the cans in ice-cream freezers and the large rectangular vessels in which artificial ice is frozen. Alumin-

ium stands next to copper and silver in heat conductivity, and its use for the last mentioned purpose would ensure a very rapid flow of heat from the contents of the cans, while the innocuity of the metal would be an additional point of superiority over the tin or galvanized-iron vessels now used.

For out-of-door exposure, as shown by the resistance to water charged with carbonic acid, the titanium or copper alloys are to be recommended. They are of about equal strength, but the copper alloy has the best color.

There are numerous purposes to which aluminium can be applied where the general requirements are fine color, strength, springiness and hardness, without particular reference to the action of the above-mentioned corroding agents. Such are, for instance, pen-holders, paper-cutters, pocket rules, match-boxes, cigar cases, combs, tongs, watch and key chains, field glasses, surveyors' instruments, mariner's sextants, and many others. For all such purposes, the German-silver alloy can be recommended as being the best adapted. Its mechanical properties have been determined by the writer, as follows:

	Cast.	*Rolled.*
Specific gravity,	2·73	2·83
	Lbs.	*Lbs.*
Elastic limit,	20,500*	40,000†
Tensile strength,	22,450*	42,040†

*Test of specimens, prepared by the writer, made on the United States testing machine at Watertown Arsenal.

†Specimens prepared by the writer, rolled hard, tested by Tinius Olsen Philadelphia.

The color of this alloy is whiter than pure aluminium; it is considerably harder, therefore, stands wear better, and in thin sheets is almost as elastic as steel.

LEHIGH UNIVERSITY, November 20, 1894.

NOTES AND COMMENTS.

A NEW PRODUCT OF THE ELECTRIC FURNACE.*—The electric smelting process, which was first developed and made manageable for industrial uses by the brothers Cowles in their now well-known electric furnace for the production of aluminium alloys, has since been studied experimentally by

* From the Secretary's monthly report, December 19, 1894.

numerous observers in the interest of pure science and the industries, and has yielded results of the most interesting nature.

The French chemist, Moissan, for example, has shown that at the enormously high temperatures which it is possible to obtain only in furnaces in which the heat of the electric arc is utilized, practically all the difficultly-reducible metals—vanadium, chromium, molybdenum, tungsten, uranium, the metals of the alkaline earths, etc.—may be de oxidized by carbon, and obtained, under suitable conditions, in the pure state.

Even more interesting, perhaps, since it opens the door to a wide and hitherto unexplored field of chemical discovery which may eventually lead to applications of the greatest value in the industries, is the observation by various experimenters of the formation of peculiar carbon compounds, either quite new, or difficultly procurable by other methods, and which, under the conditions of intense heat, only obtainable in furnaces of this kind, are formed readily and in quantity only limited by the scale on which the operation is conducted. It will only be necessary, in proof of this statement, to refer to the silicon carbide (carborundum) of Acheson, the analogous boron carbide of Moissan, the aluminium carbide of the Cowles brothers, etc. These and other analogous compounds were previously known, but, owing to the difficulty of forming them by methods heretofore available—arising chiefly from the great intensity of temperature needed for their production—their utilization for industrial purposes was not dreamed of.

The electric furnace method has shown us that these compounds and many like them can be produced in any desired quantity and at a cost which does not prohibit their commercial application. The carborundum of Acheson is at present manufactured by the ton, and although its discovery dates only a few years back, it is already recognized in the arts as a valuable addition to the class of abrasive materials.

A more recent discovery made with the aid of the electric furnace, is that of a calcium carbide (CaC_2), which, quite apart from its scientific interest, gives promise of serving several valuable uses in the arts.

This compound, like the several others named above, is not unknown to science, having been produced for the first time, in small quantity, by the distinguished chemist Wöhler, over fifty years ago, in the course of some investigations on the preparation of acetylene (C_2H_2); and analogously constituted carbides of potassium (K_2C_2), and barium (BaC_2) have been produced by various more or less indirect and costly methods.

The discovery of the method of producing the calcium carbide directly in the electric furnace was made by Mr. Thos. L. Willson, and appears to have been an unlooked-for result obtained in the course of experiments carried on at Spray, N C., for the manufacture of alloys of aluminium and calcium.

In what follows, I shall draw freely from an admirably written descriptive article on the subject, prepared by Dr. Francis Wyatt, which appears in the impression of the *Engineering and Mining Journal*, of December 15, 1894.

While attempting to produce metallic calcium in his electric furnace, Mr. Willson succeeded in obtaining from a simple mixture of lime and carbon, subjected to the heating effect of a current of 4,000 to 5,000 amperes, a fused,

black, homogeneous mass, which on cooling became solid and brittle, and which proved upon analysis to be a very pure calcium carbide of the composition CaC_2. This substance, when dropped into water, readily decomposes liberating pure acetylene with the formation of calcium hydrate, the reaction being expressed by the formula, $CaC_2 + 2H_2O = C_2H_2 + Ca(HO)_2$.

Dr. Wyatt very appropriately refers to this contribution to organic chemistry of a plentiful and cheap source of acetylene, by so easy and simple a method of manufacturing calcium carbide, as one of the most important of the valuable resources added to the chemical industry by electrical engineers. The value of the discovery was duly appreciated by its author, and arrangements have been practically consummated for undertaking the manufacture of the carbide on the large scale.

The construction of the electrical furnace designed and patented for the purpose by Mr. Willson, does not appear to differ materially from others of the type that have preceded it, embodying merely certain changes in minor details to adapt it for yielding the best results. It may, therefore, be passed over. The same comment may apply to the operative features of the process, which Dr. Wyatt describes as " decomposing, deoxidizing, or reducing refractory metallic ores or compounds by subjecting them, while intimately commingled with an excess of finely divided carbon to the continued heat of an electric arc, the mixture being between the separated electrodes." These are essential conditions of operation in every electrical furnace. The special feature, if it may be so called, appears to be embraced in the explanation that arc shall be maintained quite close to that portion of the mixture that is immediately under treatment, while reference is made to the part played by the presence of an excess of carbon in preventing violent fluctuations of electrical resistance.

Of much more direct interest are the statements given by Dr. Wyatt of the cost of manufacturing the carbide based upon the results obtained in actual practice, and his references to the probable commercial value of this new source of acetylene.

These statements we give in the author's own language, viz.:

As the actual result of its recent practice, the Willson Aluminum Company has found that it can produce one short ton of calcium carbide from a mixture of 1,200 pounds of fine coal dust and 2,000 pounds of burnt lime, and at an expenditure of about 180 electrical horse-power per hour for twelve hours. These figures are not very far from those required by theory, and they agree very closely with those given by H. Moissan, who has also produced the carbide in an electrical furnace of his own invention. It would, therefore, seem safe to formulate the approximate cost of production somewhat as follows for both the carbide and the acetylene :

1,200 pounds coal dust, say	$2 50
2,000 pounds powdered burnt lime	4 00
180 electrical horse-power from water at, say, 50 cents per hour for 12 hours	6 00
Labor, etc.	2 50
Cost per 2,000 pounds CaC_2, say	$15 00
Cost per 2,000 pounds C_2H_2, say	$37 00

These figures would hold good, not only for the present works in North Carolina, but at any other place where very cheap water-power and equally cheap coal, lime and labor are procurable and accessible.

The specific gravity of calcium carbide is 2·22 at a temperature of 18° C., and, as may be judged from its formula, it is practically insoluble in all the ordinary reagents. Its qualities and characteristics have not been fully investigated, but Moissan has found that it may be heated in hydrogen gas, or exposed to nitrogen at 1,200°, or to the contact of silicon or boron at a bright red heat, without undergoing any change, and that it is not affected by sodium or magnesium at the softening point of glass, or by tin at a red heat. At a higher temperature than a dull red heat it alloys with iron, and this is well worth noting, because it may be of interest in the future industry of steel. It becomes incandescent in contact with chlorine, bromine and iodine at the respective temperatures of 245°, 350° and 305°. It burns in oxygen, with formation of calcium carbonate, at a dull red heat, and at 500° it becomes incandescent in sulphur vapor, and yields calcium sulphide and carbon bisulphide. Water is decomposed by it very rapidly and with evolution of pure acetylene, but its action upon steam is not so rapid, even when it is red hot, and the gas evolved is not pure acetylene, but contains free hydrogen. In dilute acids it behaves in the same way as with water, but it is only slightly attacked by fuming nitric and sulphuric acids, although ordinary sulphuric acid readily decomposes it, giving off an odor of aldehyde. Dry hydrogen chloride makes it incandescent, and the gas evolved contains a large proportion of hydrogen. With fused chromic anhydride it forms carbonic anhydride with incandescence, but with a solution of chromic acid it produces acetylene only. It is oxidized by potassium chlorate or nitrate at a red heat with incandescence, and formation of calcium carbonate. Lead peroxide oxidizes it with incandescence below a red heat, the reduced lead containing calcium, and it becomes incandescent by trituration with lead chromate at the ordinary temperature.

This rapid summary of the results of preliminary investigations would seem to strengthen the opinion already expressed, that calcium carbide chiefly claims our attention as a practically unlimited and most convenient source of pure acetylene, and there is little reason to doubt that its utilization in this direction will soon cause it to be manufactured extensively in this and other countries.

The hydrocarbon acetylene is regarded by chemists, and very justly so, as one of the most important intermediate bodies in the synthesis of organic compounds from their elements, and as one of the most interesting of the entire series. It is the only hydrocarbon that can be prepared directly from its free elements when the electric arc passes between carbon poles in an atmosphere of hydrogen, and it is worthy of consideration that this combination involves heat to the amount of 61,000 units. This tremendous energy explains why the sudden decomposition of acetylene evolves enough heat to raise the temperature to 3,000°, and why the intense molecular vibration produced by detonating a minute quantity of mercuric fulminate in 25 cubic centimetres of it causes a violent explosion, accom-

panied with production of free hydrogen and finely divided carbon. It has been hitherto produced for commercial purposes by the incomplete combustion of coal gas according to the equation: $4CH_4 + 3O_2 = 6H_2O + 2C_2H_2$, and its purification has been effected by passing it through an ammoniacal solution of cuprous chloride and subsequently decomposing the red precipitate with dilute hydrochloric acid. This is, of course, a very costly and tedious operation, and is rendered a somewhat dangerous one by the highly explosive nature of copper acetylide.

It is a colorless and highly explosive gas, of very disagreeable smell, of specific gravity 0·91. It burns with a very smoky, but much more luminous, flame than olefiant gas and undergoes complete combustion when mixed with oxygen in the proportion of 1:2½ volumes. At a temperature of 1° C. and a pressure of about 725 pounds it becomes a mobile and highly refractory liquid, much lighter than water, whereas by heating it in a sealed tube it is converted into a mixture of benzene (C_6H_6) and styrolene (C_8H_8). By passing sparks through a mixture of acetylene and nitrogen, hydrocyanic acid may be synthesized from its elementary constituents $C_2H_2 + N_2 = 2HCN$, and from this there may, of course, be produced the whole series of the cyanides and a number of other important organic bodies. If the red precipitate of cuprous acetylide in a solution of ammonia be treated with metallic zinc, nascent hydrogen is produced and ethylene or olefiant gas (C_2H_4) is formed. This in its turn can be combined with sulphuric acid to form sulphethylic acid ($C_2H_4 + H_2SO_4 = C_2H_5HSO_4$); and this, on being distilled with water, yields alcohol: $C_2H_5HSO_4 + H_2O = C_2H_6O + H_2SO_4$.

The fascinating scope for intelligent and painstaking research thus opened up in so many and so varied directions, must strike all those who are in any way interested in organic chemistry as practically boundless, and the results will undoubtedly be revolutionary. For the purpose of giving us better and cheaper illumination than the ordinary coal, water and oil gases, acetylene is already occupying much attention, and it is from this direction that results will in all probability be first made apparent. The hydrocarbons of the ethylene and acetylene series give the illuminating value to gas made from the distillation of coal; while the illuminating value of water-gas is derived from a mixture, with the non-luminous gases, of the same series of luminants obtained from the vaporization and cracking of petroleum oils. Since the power of the illuminants in any gas is in direct ratio to the relative proportion of its carbon and hydrogen, it must be plain that acetylene (C_2H_2), on account of its great proportion of carbon, must be highly diluted to prevent it from burning with a smoky flame. When, however, it is diluted by mixture in proper proportion, either with water gas or with ordinary atmospheric air, its flame is smokeless and of the utmost brilliancy and whiteness. The experiments that have been made by the Electric Gas Company have satisfactorily demonstrated that one short ton of calcium carbide will produce, by merely mixing it with water, about 10,500 cubic feet of acetylene, which, when mixed with the required amount of air, produces a gas equal in illuminating value to 100,000 cubic feet of city gas of 22 to 25 candle-power, per 5-foot standard burner. If to the estimated cost already given for the

calcium carbide there be added, say, $15 per ton for freight, incidentals and profit, the material for producing such a gas could be obtained at nearly all points for 30 cents per 1,000 cubic feet, ready for burning, and the convenience with which the calcium carbide can be packed and freighted, combined with the easy preparation of the gas itself in great or small quantities, at any time, should enable it, if not to be adopted for the common supply of large cities, to supply the requirements of country hotels and dwelling-houses and of railway cars.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, December 19, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 19, 1894.

JOSEPH M. WILSON, President, in the chair.

Present, sixty-two members and five visitors.
Additions to membership since last report, eleven.
The following nominations were made, viz.:

For *President*	(to serve one year), . . .	JOSEPH M. WILSON.
" *Vice-President*	(" three years), . . .	EDWIN J. HOUSTON.
" *Secretary*	(" one year), . . .	WM. H. WAHL.
" *Treasurer*	(" " "), . . .	SAMUEL SARTAIN.
" *Auditor*	(" three years), . . .	FRANCIS LECLERC.

For *Managers* (to serve three years).

Retiring Members.	*New Nominees.*
JOHN E. CODMAN,	WM. F. BIDDLE,
GEORGE V. CRESSON,	CHARLES H. CRAMP.
EDWIN J. HOUSTON,	ALFRED C. HARRISON,
ENOCH LEWIS,	EDWARD LONGSTRETH,
JOHN LUCAS,	SAMUEL H. NEEDLES,
SAMUEL P. SADTLER,	LAWRENCE T. PAUL,
WM. H. THORNE,	CHARLES LOUIS PRINCE,
JOHN C. TRAUTWINE, JR.,	PERCIVAL ROBERTS.

For the *Committee on Science and the Arts* (to serve three years).

Retiring Members.		*New Nominees.*
C. O. C. BILLBERG,	SAM'L R. MARSHALL,	LEWIS M. HAUPT,
L. L. CHENEY,	WM. MCDEVITT,	STACY REEVES.
JAMES CHRISTIE,	C. E. RONALDSON,	
ARTHUR L. CHURCH,	L. F. RONDINELLA,	
D. E. CROSBY,	SAMUEL SARTAIN,	
J. M. EMANUEL,	T. CARPENTER SMITH,	
JOHN L GILL, JR.,	J. LOGAN FITTS,	

The Actuary transmitted the accompanying report and recommendations of the Committee on Sections, which had been approved by the Board of Man-

agers, at the stated meeting of the Board, held Wednesday, November 14, 1894:

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, PA., November 14, 1894.

The Committee on Sections, directed by resolution of the Board of Managers to consider the expediency of sub dividing the membership of the Institute into sections, has given the subject its careful attention, and reports as follows:

The committee, at the outset, is impressed with the fact that, of the nearly two thousand persons comprising the membership of the Institute, a comparatively small proportion only is actively interested in its work. The principal reason for this circumstance, the committee believes, is to be sought in the fact that, by the present organization of the Institute, the educational and scientific work is left largely in the hands of the Secretary and the Committee on Instruction.

Chiefly on this account, members now have neither the opportunity nor the stimulus to take the initiative in scientific and technical work.

The subdivision of the membership into departments or sections representing various branches of science and the arts—each section having control of its own domestic affairs, but all subordinate to the general authority of the Institute—would, it is believed, afford the opportunity needed to induce the general body of the membership to engage actively in the cultivation of special branches of pure and applied science; and this opportunity being afforded, it is not unreasonable to expect that the needful stimulus for the prosecution of active work would come, from the feeling of responsibility and the desire to make a creditable record with which each of these departments would be permeated, but chiefly from the individual interest of members which would grow with the development of the work of each department

The committee foresees the difficulty in the way of an early realization of such beneficent results The most serious of these difficulties, probably, will be that of finding the right men to undertake the task of organizing the new departments from time to time, and of directing the work of each in such ways as to create the interest essential to success.

This is the vital point of the new project, and to accomplish the results aimed at, the committee believes it will be most important to proceed with deliberation, and to attempt the creation of new departments only after the most careful weighing of the probabilities of success or failure.

To the manifest difficulty of inducing the present members to adapt themselves to so great a change in the working methods of the Institute, also, there must be added the hindrance opposed by the present uninviting quarters in which we are housed and the lack of many desirable facilities.

After giving due consideration to the subject in all its aspects, however, the committee believes that the broadening of the field of usefulness of the Institute that would follow from the successful realization of a project of this kind, presents the prospect of such incontestable advantages, that a proper effort to carry it into execution should be made. Even should it prove a failure, the Institute would still be in its present position as to its scientific organization, and would consequently lose nothing in making the experiment.

The committee, in conclusion, submits the following recommendations:

"That the membership of the Institute be subdivided into sections (substantially after the pattern of the sections now in existence), which sections shall be organized from time to time, as, in the discretion of the Board of Managers, may be found expedient;

"That the expenses of the sections now in existence, or which may hereafter be organized, be assumed by the Institute and provided for in the usual manner by annual appropriations; and,

"That this committee, or a special committee appointed for the purpose, be authorized to prepare the needful amendments to the By-laws of the Institute to carry the foregoing propositions into effect."

At a special meeting of the Committee on Sections, held Wednesday, the 14th inst., at which were present Messrs. Jayne, Pemberton, Thorne and the Secretary, the foregoing report was adopted and ordered to be transmitted to the Board of Managers.

[SIGNED] H. W. JAYNE, *Chairman.*

Reported to the Board of Managers and approved Wednesday, November 14, 1894.

[SIGNED] H. L. HEYL, *Actuary.*

In accordance with the foregoing action of the Board of Managers, the following substitute for Article XI, of the By-laws, relating to the "Organization and Government of Sections," is recommended by the Board for adoption by the Institute as an amendment to the By-laws, with the object of promoting the growth and utility of the Sections:

ARTICLE XI.

ORGANIZATION AND GOVERNMENT OF SECTIONS.

SECTION 1. For the promotion and encouragement of manufactures and the mechanic arts, as well as of the sciences connected with them, members of the Franklin Institute may form sections and hold meetings in the Hall, or such other rooms as may be provided for them by the Board of Managers. These sections shall be constituted as hereinafter provided, and shall have precedence in the order of their formation.

SEC. 2. Any number of members, not less than twelve, may constitute a section.

SEC. 3. Members desiring to form a section shall make written application to that effect to the Committee on Sectional Arrangements, which committee shall report such applications, from time to time, to the Board of Managers at one of its stated meetings, with such recommendation as the committee may deem it expedient to make in each case.

An application for the formation of a section shall be made in the following form:

"The undersigned, members of the Franklin Institute, request that they may be constituted the ——— Section of the Franklin Institute."

This application, when submitted by the Committee on Sectional Arrangements, shall be considered by the Board of Managers, and, if approved by the Board, the section shall be established and the names of the petitioners shall be recorded on the minutes as the founders of that section, and shall be reported by the Board of Managers to the Institute at its next meeting. Whenever the petitioners have organized, they shall report such organization, with the names of their officers, to the Committee on Sectional Arrangements. But if they shall fail to organize such section within six months after the date of said approval, or if an established section shall fail to make a report of its proceedings to the Committee during any period of twelve months, it shall be the duty of the Committee on Sectional Arrangements to inform the Board of Managers, which may thereupon declare that such section is extinct.

SEC 4. All members of the Institute shall have the privilege of enrolling themselves, without payment of additional fees, as members of any of the sections which are now, or which may hereafter be, established in conformity with these By-laws, and such enrollments shall be reported from month to month to the secretaries of the sections designated; but no person shall be entitled to any of the privileges of

any of the sections who has not complied with the conditions of Section 3 of Article III of these By-laws.

SEC. 5. Each section shall submit to the Committee on Sectional Arrangements prior to the stated meeting of the Board of Managers in December of each year, an estimate of moneys it will require for the ensuing year, and such estimate the Committee on Sectional Arrangements shall transmit, with its recommendation, to the Board at its stated meeting in December.

SEC. 6. Each section shall elect its own officers and make its own by-laws, not inconsistent with the Charter and By-laws of the Franklin Institute. The Institute shall not be responsible for bills contracted by any section except in conformity with the conditions prescribed in Section 4, of Article XII, of the By-laws relating to committees, nor in any event for a sum greater in any one year than the amount appropriated by the Board of Managers for the service of the section for that year.

SEC. 7. All requisitions for supplies shall be made by order upon the Actuary of the Institute.

SEC. 8. The books, papers, apparatus, specimens, models, and all other collections of each section shall be the property of the Institute, held for the use of that section. Donations of objects or books to or for any section, shall be received and reported to the Committee on Sectional Arrangements, and by this committee to the Board of Managers, as donations to the Institute for the use of that section.

SEC. 9. At the first meeting of each section it shall determine, subject to the approval of the Board of Managers, the times of its stated meetings.

SEC. 10. Papers read and lectures delivered before any section and approved by the same, shall be referred to the Committee on Publications of the Institute, and, if accepted by them, shall be published in the *Journal of the Institute*.

SEC. 11. Societies now existing, or which may hereafter be founded, for the consideration of any subjects clearly within the scope of the Franklin Institute, and which societies may desire to unite with the Franklin Institute as sections, shall furnish a list of such of their members as have declared their willingness to become members of the Institute, to the Committee on Sectional Arrangements, which committee shall transmit the same, with its recommendation, to the Board of Managers.

SEC. 12. On all points not herein provided for, each section shall be governed by the Charter, By-laws and usages of the Institute.

On Mr. Heyl's motion, the amendment was ordered to publication.

Mr. John H. Cooper read an historical sketch of the evolution of the tangential water-wheel, illustrating his remarks with a specimen of the Pelton water motor and with a number of lantern slides. (Referred for publication.)

Mr. Snedeker exhibited and described a new form of typewriting machine, called the "Duplex" typewriter, the chief peculiarity of which lies in the employment of a double bank of keys, by which it is made possible to strike and print two letters or symbols simultaneously, one with each hand.

Mr. W. N. Jennings exhibited a number of characteristic photographs of the Penn statue, recently completed in aluminum-bronze by the Tacony Iron and Metal Company, from the design of Mr. Alexander Calder. The statue is now in its appointed place, on the dome of the City Hall.

The Secretary presented his monthly report. Among the novelties shown was an engraved portrait on silver, executed by Mr. Leslie S. Marshall, of Boston. Adjourned.

WM. H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIX. FEBRUARY, 1895. NO. 2

MECHANISM OF THE POCKET WATCH.*

BY H. E. DUNCAN.

The lecturer was introduced by Dr. Coleman Sellers, Professor of Mechanics, and spoke as follows:

LADIES AND GENTLEMEN:

Of the several branches of fine mechanics, that of horology has ever been one of the most fascinating. Like most of the useful arts, its early history is wrapped in more or less of mystery. Early writers mention the fact of the existence, in their times, of mechanical devices for the purpose of measuring time, but usually leave the reader in doubt as to the mechanical design or plan upon which they were constructed. Writers as early as the eleventh century make such mention. The earliest productions, in all branches of horology, were very crude, and their mechanical construction such as would

* A lecture delivered before the Franklin Institute, December 7, 1894.

be expected where the workman entered an unexplored field in which he was so sadly handicapped by lack of suitable tools and of the knowledge necessary to make them.

Watchmaking, so-called, or the construction of a portable time-piece of such size as to be readily carried upon the person, must have severely taxed the mechanical abilities and the patience of the artisan; but, as I have mentioned, there is a certain fascination to one mechanically inclined, who enters this branch of fine mechanics. I imagine these pioneers in watchmaking caught this fever, and that they could not stop, if they would, until death relieved them from its fascination.

This I call the Infant Age of watchmaking. I am of the opinion that there is not at present in existence a watch of this age.

It is not the purpose of this paper to deal with the watch historically, beyond presenting what is necessary to convey to you an idea of the particular basis upon which the *American system* of watch manufacture was established. With regard to these earlier watches, I will only remark that they had but one hand, and that they served only to mark the hours in a very indifferent manner. The next period of advance worthy of note is one that I call the Age of Handicraft. This period is marked as one in which the workman showed great progress in the mechanical execution of his work. He learned to execute parts in a very delicate manner, to give them graceful shapes, and to polish, in a masterly manner, those parts made of steel—his gain in handicraft enabling him to make movements in many odd forms and sizes. Artists in gold, silver and enamel, made and decorated cases for his movements. Most beautiful specimens of these cases are to be found in many collections of the present time. These watches were most artistic throughout, in *appearance*, but they still remained of but little value as time-keepers.

From this stage the improvement in time-keeping qualities becomes very marked. Large bounties were offered by Act of Parliament for portable time-pieces sufficiently accurate to ascertain the longitude at sea. These awards

were not for elaborate cases, or for fancy polish of mechanical parts, but for *actual performance* as time-keepers.

This period was one in which the watchmakers made a study of the laws of physics, and made practical application of them in the construction of ships' chronometers, and with such good results that, by the year 1769, there had been paid to Harrison the sum of £10,500.

It was but a step to reduce the size of this time-piece to a convenient pocket size, and watchmaking entered its scientific age. At first glance it might appear that with a knowledge of the scientific laws to be observed in the construction of watches, and with workmen sufficiently skilled in handicraft to execute them, watchmaking had reached its final stage of development. If the product of *hand labor* had been equal, in mechanical accuracy, to that of machines, this condition would have been reached, but such was not the case. Results obtained by instruments of precision depend almost entirely on the absolutely uniform operation of automatic mechanism; while, notwithstanding the highest degree of manual skill, the quality of the final product of his handicraft will still be affected by the personal equation of the workman.

This brings us, then, to the next great event in watchmaking; one falling within the present century, and due wholly to American mechanics:

THE MECHANICAL AGE OF WATCHMAKING.

The American system was not based upon new scientific discoveries, or upon any radical change in existing models, but it revolutionized the method of manufacture.

In place of some tool or fixture guided by the hand of a workman, a machine was constructed, especially adapted to the piece to be made, cams and levers taking the place of the hand and eye of the workman, the result being greater accuracy in the finished piece, and, consequently, a closer approach to perfection in the watch as a whole.

For many years American watch factories had machines for making but few models of watches, but to-day the American Waltham Company has a plant in which it can

produce a watch of any design or size of model that the world's market may demand.

In mechanical accuracy, time-keeping qualities and price, it cannot be equaled.

The pocket watch is one of the most accurate of all instruments of precision. Briefly defined, it is, mechanically, a spring motor, of most delicate construction of parts, controlled by an automatic regulating device that is a marvel of precision. It is designed to measure accurately and record the hours, minutes and seconds of the mean solar day. A watch, keeping time to a minute a week, varies from true precision by only one hundredth of one per cent. The act of winding, so-called, is that of storing energy in a spring. By this act of winding, the hand, in an interval of about fifteen seconds, stores up energy enough to keep the motor in motion and to supply the maximum of power required, for a period of twenty-four hours, and with a reserve, in the *modern* watch, of about sixteen hours; or, in other words, the modern Waltham watch will run for a period of forty hours from the energy that is stored in it by the hand in fifteen seconds of winding—9,600 times the length of time employed in winding.

The storage of power is effected by means of a ribbon of steel, of a width and thickness proportioned to the size of the watch, and contained in the first wheel, called in technical parlance the barrel, which is in the form of a cup. The size of this cup is governed by the size of the watch, being of nearly one-half the diameter of the frames of the watch.

This spring, in its natural form, is of the shape shown on the screen, and is from eighteen to twenty-five inches long. It is coiled up in the barrel, with its outer end secured by means of a pierced hole fitting over a suitable hook or stud projecting inward from the barrel. Its inner end is secured, by a similar hook, to the hub of a wheel called the first or main wheel. By the act of winding, this spring is wrapped around this hub, and the wheel is caused to revolve. The tension imparted to the spring in winding it about this arbor, is the force tending to drive this first wheel of the watch. The moment of this force is equal, on an average

in a watch of "gentleman's size," to that of a pull of five ounces troy on a wheel of one inch radius. The action of the spring, in performing its duties in the watch, will readily be understood by observing the one on the screen.

To show, in the most simple manner, the hours, minutes and seconds of the mean solar day by three separate hands or pointers would require three wheels or gears, with such ratios of diameters and teeth, that *one* wheel would make one revolution in twelve hours; the next, twelve revolutions in this time; and the third, 720 revolutions. But this simple plan would give two hands going in one direction and the third hand in the opposite direction, while custom demands that the hands of a watch shall all move in the same direction. To correct this reverse motion of the third hand, two more wheels are required, and their use, in other respects also, is beneficial rather than otherwise.

The wheels and pinions, or, technically speaking, the train of a watch, is a system of gearing driven by the stored energy in the main-spring. These wheels and pinions are so proportioned to one another in respect of their diameters and numbers of teeth, that when driven at the proper rate of speed they will serve to register hours, minutes and seconds by means of hands fixed to them.

The necessary frames to hold these wheels and pinions are called plates—the upper and the lower plate. The train of wheels would perform the work required of it just as efficiently if the wheels were arranged with their axes in a straight line, and for the present I will use this arrangement in my explanations.

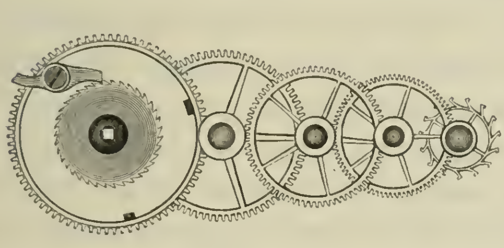


FIG. 1.

This arrangement is seen in *Fig. 1*. At the left we have the main-spring in its barrel. This drives a steel pinion, that has fixed to it a wheel No. 2, technically known as the centre wheel and pinion. This centre wheel and pinion is intended to revolve once in an hour. It is the wheel to which the minute hand is fixed. It serves to mark the

fractions of an hour expressed in minutes. In turn, this centre wheel drives pinion and wheel No. 3. This is called the third wheel and pinion. This third wheel, in turn, drives pinion and wheel No. 4. This fourth wheel revolves once a minute, or sixty times faster than the centre wheel. It is to this wheel that the second hand is fixed. Returning to the third wheel, I will explain that its use is to cause the fourth wheel to revolve in the same direction as the centre wheel, so that the hands will move in the same direction. It is also useful in allowing the distance between the centre and fourth wheels, to be varied. Otherwise the distance apart of the minute and second hands on the dial, would be governed by the size of the centre wheel and fourth wheel pinion.

You will note that there is one more wheel and pinion in this train of wheels, namely, the last one, which is called the escape wheel and pinion, but, as it belongs to the time-governing part of the watch, called collectively the escapement, I will speak of it under that head.

I now place on the screen the train wheels of a Waltham watch, with the main-spring fully wound. When the brake is removed, all begin to revolve rapidly, as you see, and they will continue to do so until all the stored-up energy of the main-spring is exhausted. The watch has now run down, but the wheels have made as many revolutions as they would have done in running forty hours or more. Each of the wheels has traveled at its proper relative speed; that is, the fourth wheel, showing seconds, has traveled sixty times as fast as the centre wheel (the wheel that marks the minutes), but it has not served to measure time, because of the lack of any contrivance to govern or regulate the speed.

This controlling or regulating device is called the escapement.

The detached lever escapement was invented about the year 1765 by Thomas Mudge, a famous English watchmaker. It is the escapement used at present in nearly all good, sound pocket watches. It can be said for it that, when made with ordinary care, it is so reliable in its action

that it is generally selected in preference to all other escapements for pocket watches.

The action of this escapement is to bring to a standstill every wheel in the train, and, after a brief period of rest, to allow the train to start again, only to be as quickly stopped again, and so on. These alternate steps of progress and halt succeed each other so rapidly, however, that probably very few persons realize that the motion of the time train is always intermittent, and not uniformly continuous.

With the exception of the escape wheel, the teeth of all the wheels of a watch are formed on the epicycloidal curve, so as to mesh into, and give motion to, the several pinions with the least friction or loss of power. The teeth of the escape wheel are for a different purpose, and they act in an entirely different manner.

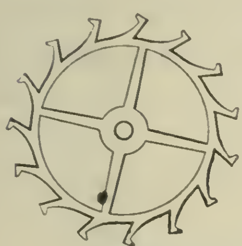


FIG. 2.

You will notice by *Fig. 2* that the teeth are not in radial lines, but are so inclined as to form a series of hooks. Also notice that the ends of the teeth are of a wedge form. The angle formed by the straight sides of the teeth and the inclined top is called the locking corner, and the angle of the inclined top is called the impulse or lifting face. Engaging with the wheel is a piece called the "pallets and fork," and of the form shown on the screen (*Fig. 3*). The pallets are shown by the two black projections or horns, and are made of some kind of precious stone, such as sapphire, ruby or garnet. The remaining part is of steel, and serves to hold these pallet stones in place.

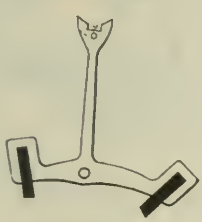


FIG. 3.

The long arm with divided end is, from its shape, called the fork. The fork and pallets are mounted on an arbor that allows them to swing or vibrate, and placed so close to the escape wheel that one or the other of these pallet stones is sure to lock into a tooth of the wheel. By means of the accompanying sketches I will endeavor to explain the action of the escape wheel and pallets.

Fig. 4 shows the escape wheel with one of its teeth resting against the left-hand, or so-called receiving, pallet stone. It is now in the position called "locked" or "at rest," and it

will remain in this condition until, from some cause, this pallet is moved backward sufficiently to permit the locking corner of the tooth to pass this flat face of the pallet stone. The wedge-shaped end of the tooth will then still further lift, or move the pallet, as shown in *Fig. 5*, and it will continue to lift the pallet until the wheel is free to pass under it, when a tooth, in advance of the one in question, will be caught by its locking-corner on the face of the other, or so-called releasing, pallet-stone, as shown in *Fig. 6*. Here it will remain until the pallet is withdrawn sufficiently to allow the tooth to pass under, when the former action will take place at this point, and the wheel will again be

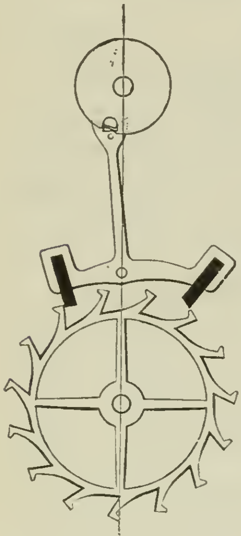


FIG. 4.

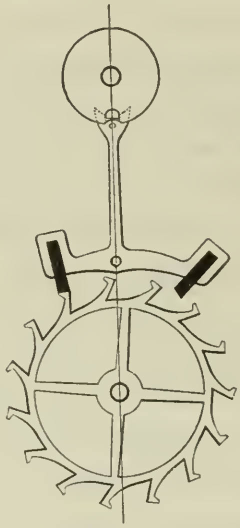


FIG. 5.

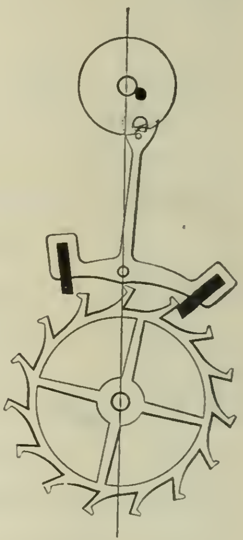


FIG. 6.

brought to rest, in the position noted in *Fig. 4*. Here we have the rotation of the escape-wheel converted into vibrating motion at the pallets. The long arm serves to increase this angular movement, and it is the medium through which this vibrating motion is communicated to the balance through what is called a roller (*Fig. 7*). This is a small disk with a pin near the outer edge, made, as the pallet-stones are, from some precious mineral. This disk is shown, with its pin, at the upper part of *Figs. 4, 5* and *6*. It is on the same arbor as the balance and hair-spring, and it moves with them as they vibrate.

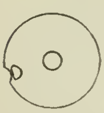


FIG. 7.

Imagine the roller and pin, shown in *Fig. 4*, to be, by some cause, rotated slightly to the right and toward the slot in the end of the fork. The pin would then enter and strike against one side of the slot in the end of the fork, and move, together with the pallets, in the same direction until the escape-wheel tooth was unlocked, when the lifting end of the tooth, passing under the pallet on that side, would continue to drive the fork to the right. This, in turn, would assist the pin in the same direction, as shown in *Fig. 5*, until it passed beyond this influence, as shown in *Fig. 6*. Here the "fork and pallets" await its return that it may first and then give impulse, in the opposite direction, through unlock this roller and pin, to the balance.

This act of unlocking, that it may receive impulse, is, in the case of clocks, performed by the pendulum, acting under

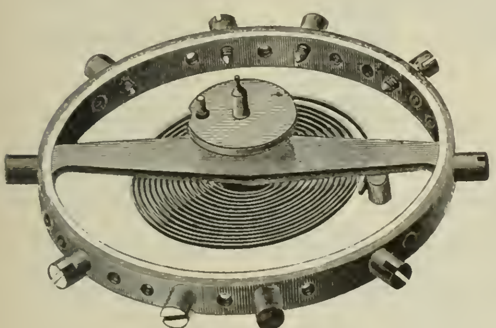


FIG. 8.

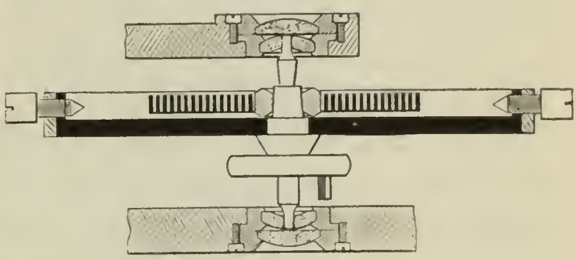


FIG. 9.

the laws of gravity; while in portable time-pieces, the balance takes the place of the pendulum, and the hair-spring that of the force of gravity. The balance, hair-spring and roller are all mounted on a staff, or arbor, *Fig. 8*, which runs on very delicate pivots, or bearings, not much larger than an ordinary hair. I show you now, on the screen, a very striking camparative illustration of the size of these pivots, namely, a photograph of the largest balance pivot used at the Waltham factory, and the eye of a No. 10 sewing needle, made with the aid of a microscope. These pivots run in jeweled holes, with additional jewels, called end stones, at their ends.

You will see by *Fig. 9*, that the pivot will always rest on jewels, in whatever position the watch may rest. These

fine jewels shown are the ones usually broken in case of accident to the watch. The balance wheel will be explained later. It is placed midway of the staff; and above it is placed the hair-spring, a very delicate spring made from a flat piece of steel wire, about nine inches long, one-hundreth of an inch wide, and two and one-half thousandths of an inch thick, weighing about 9,000 to the pound. This spring is shown in *Fig. 10*. It is coiled in the form of a flat spiral, having its inner end made fast to a little split collar, known as the collet, which collar is forced on to the balance staff or arbor.

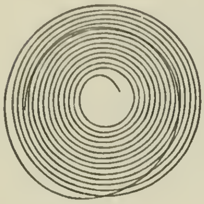


Fig. 10.

The outer end of the hair-spring is pinned firmly to a small stud, called the balance cock, which is held rigidly to some part of the frame of the watch.

The relation existing between balance and spring will be understood with the assistance of the model thrown on the screen.

Taking hold of the balance and moving it from its present place of rest, say one-half turn or more, the spring will be put in a state of stress, and, when we release it, this condition of the spring will at once carry it back to its normal position, and the acquired momentum of the balance will carry it far beyond that point, but, in so doing, it will put the spring in a state of stress, in a direction opposite to that in which we strained it by turning the balance by hand.

When the momentum of the balance ceases to exceed the opposing force of the hair-spring, the revolution of the balance in that direction will cease, and immediately the hair-spring, will begin to act, carrying the balance back again; but, as in the former case, the momentum of the balance will carry it beyond the point of rest, and so the motion will be repeated, in alternate directions, each vibration being shorter than the preceding one, until the balance finally comes to a stop. It is this action of the balance and spring that is made use of to unlock the escape wheel, as the balance is returning from its excursion. This is done by the action of the roller and pin that move with the

balance on its staff. As the balance returns from either direction, *Fig. 4* or *6*, toward the point of rest, *Fig. 5*, the roller pin engages with the slot in the fork, and the momentum of the balance and the tension of the spring, are sufficient to unlock, without apparent effort, the escape wheel. The instant this takes place, the wheel, by reason of the form of its tooth, and urged by the power of the main-spring, instantly avails itself of the position of the roller pin in the fork, and gives the balance a push, as it were, in the direction of its motion. This push, or impulse, is sufficient to make up for all loss, due to friction and other

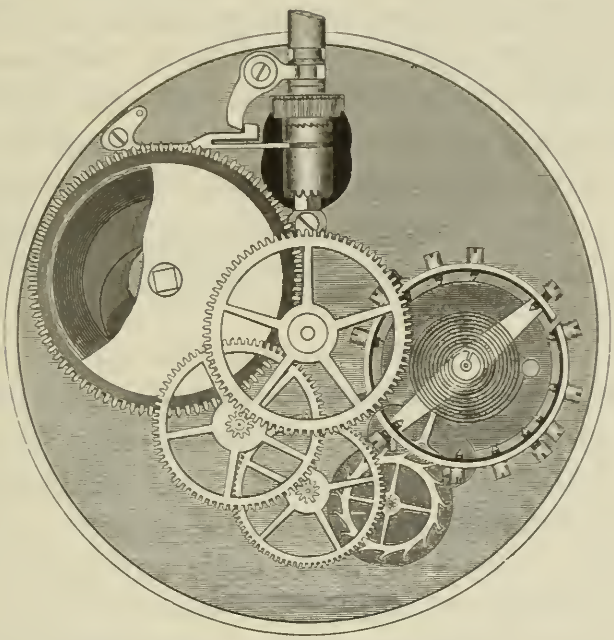


FIG. 11.

causes, which, but for this impulse, would, in a short time, bring the balance to a state of rest.

At each excursion of the balance, it has work to do in unlocking the escape wheel, and in turn it receives enough new energy to keep up its full motion. These pulsations are very rapid, five each second, 18,000 each hour—almost too rapid for the eye to follow. I place on the screen a very slow moving watch that you may better study its action. * * *

For simplicity, I have illustrated the watch with its train

and escapement arranged in a straight line, but this, of course, is not the actual arrangement in the watch. Here in the watch, *Fig. 11*, the wheels of the train are arranged between circular frames, with the centre wheel, as its name would lead us to imagine, placed in the centre of the frame. By arranging the hour and the minute hands concentrically, one series of graduations upon the dial is made to serve for both, and the use of the third wheel allows a little leeway in planting the position of the second hands, when the watch is designed, relative to its distance from the other hands, in the centre of the watch. Custom demands that in a watch movement, cased in a hunting case, the figure III on the dial shall be placed at the pendant and bow, or ring, to which the chain is attached, while in the open-face watch the pendant must be at the figure XII. In both cases, the second hand must be on a line from the centre of the dial to the figure VI. In stem-winding watches this requires two models, or arrangements of train, in order that the winding connections in the movement shall be in line with that of the case.

I have thus far illustrated only the plan of the watch, that is, a view such as would be obtained by looking down upon it. I now show another view, equally important, that is properly called the elevation. This permits us to look between the frames, and to see the position of the parts, which I trust you will recall by their names, as well as their arrangement when viewed from above. It will also permit me to explain the arrangement of two wheels and pinions, which serve to cause the hour hand to make but one revolution around the dial, while the minute hand is making twelve.

The centre wheel has one of its arbors long enough to reach through the watch frames on the dial side, and has, fitting on it, friction-tight, a steel pinion, called the cannon pinion. This pinion drives a wheel in a recess in the plate, a wheel usually three times its size; and a pinion, fixed to this wheel, in turn drives a wheel four times its diameter, with a centre in the form of a tube nearly as long as the cannon pinion and fitting freely around it. This arrange-

ment of sizes causes this last or hour wheel to move twelve times slower than the cannon pinion. To the cannon is fixed a minute hand; to the hour wheel, the hour hand. The spring friction of the cannon pinion, in the arbor of the centre wheel, permits this set of wheels to slip, thus avoiding injury to the train or escapement in setting the watch.

* * *

I will return for a moment to the balance and hair-spring, which I called the automatic governor of this spring motor.

Without touching upon the constantly occurring and often violent and sudden changes in the position of the watch, I will consider the effects of temperature, which is constantly varying, and often quickly and between wide limits. The structure of the hair-spring of the watch, presenting, as it does, so much surface, in proportion to its total mass, is such as to render it particularly sensitive to thermic influences. It is a well-known law of nature that all metals expand under the influence of heat, and that springs lose something of their elasticity with a rise in temperature.

Applying these laws, it is found that heat causes the balance to increase in diameter, and the hair-spring to lose some of its elasticity. From these two causes the watch loses time by a rise in temperature, while the opposite effect will be produced by a fall in temperature. The effect of temperature on balance and spring is corrected by what is called the compensating balance, invented about the year 1782. This is so constructed that the same heat which weakens the elastic force of the hair spring, serves at the same time to reduce the diameter of the balance, so as to exactly adapt it to the force which the weakened spring is capable of exerting. This automatic compensation is obtained by constructing the balance rim of two metals, having widely differing ratios of expansion. In the ordinary watch, the two metals employed are brass and steel. The inner portion of the rim being of steel, with an encircling band of brass, and the two metals being firmly united by fusion, the action of this form of a balance will readily

be understood by a few words of explanation in connection with the diagrams on the screen.

Fig. 12 represents two strips of metal, brass and steel, of equal length at normal temperature. Under the influence of heat, or of cold, these strips will expand, or contract, in about the ratio indicated by the dotted lines. Now, if the brass were firmly united to the steel, as in *Fig. 13*, and if their respective thicknesses were in the ratio of three of brass to two of steel—then the brass would not be free to expand, or contract, being held by its union with the less expansive steel, and the result would be that, when heated, the bar would curve, as in *Fig. 14*, while, when cooled, it would curve in the opposite direction, as shown in *Fig. 15*.

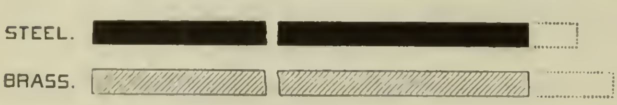


FIG. 12.

FIG. 13.

FIG. 14.

FIG. 15.

The next two figures will show how this law of expansion is utilized in the construction of compensating balances.

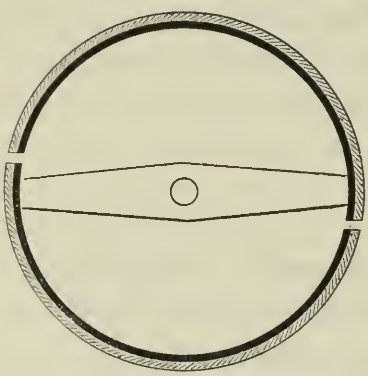


FIG. 16.

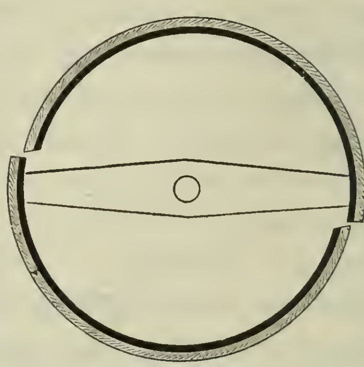


FIG. 17.

The first of these, *Fig. 16*, shows the balance with its rim of brass and steel, at normal temperature; the next, *Fig. 17*, shows the form it assumes when heated. You will

observe that the rim of the balance has been severed at two opposite points and near the arms, leaving the cut ends free to move out or in, by changes of temperature. In the next drawing, *Fig. 18*, you will notice that the balance has received an addition in the shape of screws with large heads.

These have a double use. First: to give the balance the exact weight desired, so that, in conjunction with a proper hair spring, it shall make the exact number of vibrations required per hour, which in most modern watches is 18,000. In making this number of vibrations, the rim of an ordinary balance will travel 3,479 feet, or nearly eighteen miles per day. Now, if for any reason the balance were to omit only ten of these vibrations in an hour, the watch would

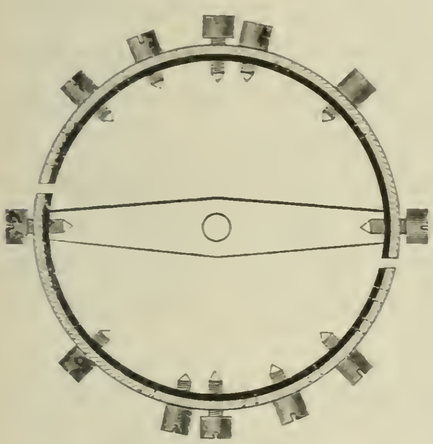


FIG. 18.

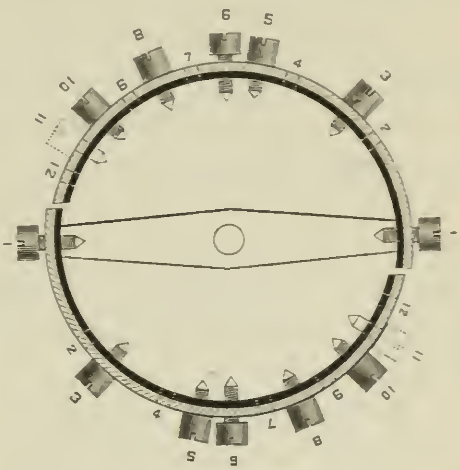


FIG. 19.

have lost two seconds of time, or forty-eight seconds per day, over three-fourths of a minute. The addition of one of these little screws to each side of the balance, will reduce the number of its vibrations, amounting, in some conditions, to as much as ninety-eight seconds per hour, or thirty-nine minutes per day.

I will now make plain to you the second use of these little screws. In this view we have the screws numbered, *Fig. 19*, and you will observe that between the screws are holes, which are adapted to receive screws, and these holes are also numbered. A careful and accurate trial might show that at a normal temperature (about 70° Fah.), this balance would have the proper size to give its required number of

vibrations, but by subjecting the watch to an increase of twenty-five degrees in temperature, it might be found to lose as much as seven seconds per hour, or thirty-five vibrations. This fact will indicate that when in heat the balance is too large; or, more properly stated, the effective weight is not properly located, being too far from the axis. In this case we would move screw No. 3 to position marked No. 11, thus giving an added weight to that part of the rim where the effect of the heat would cause it to curl in toward the axis and thus allow more rapid vibrations.

Manipulations of this sort are always required in adjusting watches to temperature.

I now show on the screen the motion of a watch balance in heat, that you may note this action. * * * * * *

As early as the year 1837, European horologists endeavored to account for unexpected changes of rate in ship chronometers on the theory that their balances were influenced by magnetism due to the magnetic polarity of the earth.

Experimental balances were made of many non-magnetic metals that would not be influenced by such lines of force. By these experiments it was proved that the earth's magnetism was not the prime cause of that error of rate which it was sought to remove.

At the present time the magnetization of pocket watches by induction from the many sources of electric current now so commonly in use, makes the question of furnishing a non-magnetizable watch one of the prominent problems of modern watch manufacture.

A pocket watch will show but little if any change of rate that can be traced directly to the influence of magnetism due to the earth's polarity, but by placing the watch within the influence of an intense artificial magnetic field its rate will be seriously affected. Magnetic fields, of an intensity sufficient to stop the watch, are to be found on every hand, and if the wearer knowingly or otherwise, ventures into the lines of force, the watch will instantly adapt itself to the well-known laws of magnetic induction.

There are two well known laws of magnetism that apply to watches.

The first is that any so-called magnetic metal, placed in the field of a magnet, will itself become a magnet, and will retain this magnetism in a more or less marked degree when removed from the field. Steel is an excellent example of such metals.

The second law is that similar magnetic poles repel, and dissimilar poles attract, each other.

By applying these laws we arrive at a full understanding of the effect of magnetism on a pocket watch of the usual construction, and an explanation of its loss of value as a timekeeper.

A watch, in the field of a magnet strong enough to stop it, will usually, when removed, at once commence running again, but its time-keeping qualities will have been ruined. It is true that it can be de-magnetized, but this, while a relief, is no permanent cure, and the watch will again become magnetized upon similar exposure.

On the screen we have the shadow of a magnetized piece of steel called a magnetic needle.

You will note that when the horse-shoe magnet approaches the needle, the latter assumes a condition of sympathy with the magnet's polarity, but when we reverse the magnet, the needle at once reverses its position so as to conform to the previous conditions of attraction and repulsion of magnetic poles.

The horse-shoe magnet is the stronger of the two, and the needle, being free to revolve, responds to its polarity. If the needle were not free to move, the horse-shoe magnet would reverse the magnetism of the needle. * * *

It is safe to say that in the majority of cases, when watches have been found to be magnetized, it has happened at some time unknown to the wearer, who has wandered into the field of a powerful motor or dynamo. When a watch stops in a magnetic field, it is because the magnetism is strong enough to hold the balance.

A magnetized watch has a very irregular rate. A marked gain or loss of time will usually be followed by the opposite condition, these alterations varying in quantity at different hours of the day. The more marked the polarity

of the watch, the greater will this variation become. In the pocket watch, we have in particular two pieces of steel that absorb and retain magnetism, when brought into the field of a magnet. I allude to the main spring and the balance (see *Fig. 9*). The former, owing to its mass and hardness, is the greater quantity. The spring, as you will recall, is a long ribbon of steel, in a cup or barrel, which, when fully wound, is in a small coil, in the centre of the barrel, wrapped around the arbor, and, when run-down, is in much larger coils, which have expanded until they have filled the barrel. We have here, at the extremes of fully-wound and run-down, two laminated rings of magnetized steel that show polarity, but the direction of this polarity changes as the spring passes from the condition of fully-wound to that of run-down.

Here we have a magnet that changes its polarity through the whole period during which the spring is passing through its changes in driving the watch. The other particularly important part of the watch in the study of the problem, is the balance. You will recall that its arms and part of its rim are of steel. They consequently become polarized, but this polarity, unlike that of the main-spring, remains a *constant* factor. In the case of the coiled main-spring, its polarity appears to take nothing from the stored-up energy of the spring, but in the balance we have a different condition. We have done all that could be done to remove friction, or to make it constant, and to eliminate the factor of change of rate by changes of temperature, only to meet, in our polarized balance, a new factor, due to one of the laws of magnetism that I have stated. Its poles will be attracted, or repelled, by other polarized bodies near it. When the balance is in place in the watch and free from any influence of the train, its spring should return to the same place of rest or quiescent point. This place of rest is one in which its spring is free from tension; but the moment the balance becomes polarized, it immediately tries to place itself in sympathy with this new condition, and disregards the previous relations with its spring in regard to the place of rest. There is at once established in

the spring a state of stress to oppose this. The spring is no longer natural in its action. Were all these disturbing elements constant factors, the result would be a constant error (*Fig. 20*).

But this is not the case. The polarized main-spring is constantly revolving and presenting its ever-changing magnetic poles to those of the balance. At times these are in sympathy with its own polarity; again they are exactly opposite. In one case the balance will make its excursions too quickly, in the other not quickly enough.

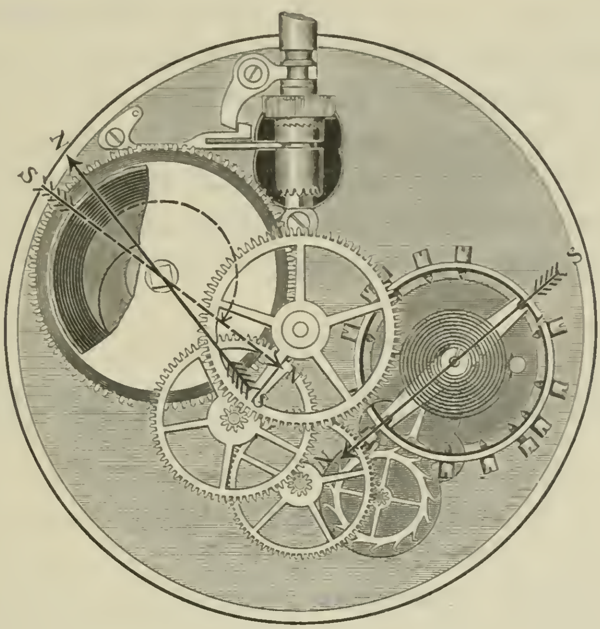


FIG. 20.

In one case the watch gains, in the other it loses. I have on the screen a magnetized balance and spring in the position they occupy when in the watch. A test by a small compass needle shows them to be polarized. Vibrate the balance and it returns to its former place, which is in sympathy with the polarity of the steel spring in the barrel. We revolve the barrel a little and the polarity changes and the position of the balance responds to the change of polarity presented by the barrel. * * *

The hair-spring comes under these laws, but, being less in mass than the balance, its polarity is not so important a factor.

But the slide on the screen shows a balance of non-magnetic metals with the usual steel hair-spring, and you will see it is a little influenced by the polarity of the main spring.

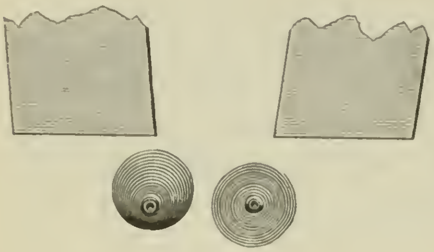


FIG. 21.

I have on the screen two watch hair-springs (*Fig. 21*); one of non-magnetic metal, the other of the usual metal, steel. The magnet serves to distinguish them. * * *

A non-magnetic watch is one in which all the governing parts are of non-magnetic metal. Magnetism will not affect the time-keeping qualities of such watches. * * *

I show you finally on the screen the action of the magnet on two watches, one of the usual construction, the other with all its governing parts of metal such as is used in the Waltham non-magnetic watch. * * *

THE ANIMAL AS A PRIME MOVER.

BY R. H. THURSTON.

PART II. ENERGY SUPPLIED; POWER AND EFFICIENCY; INTERNAL WORK OF THE VITAL MACHINE.

The energy expended by the vital machine consists of:

(1) The external work performed as the task of the workingman.

(2) The external work performed incidentally outside of that useful work, as in the movements of the limbs, walking, handling the food and various voluntary and other motions, which constitute a considerable fraction of the more or less necessary expenditure of energy in ways not included in the daily specified task.

(3) The internal work of digestion, assimilation, nutrition, and rejection of excreta.

(4) The internal work of respiration.

(5) The internal work of circulation of the blood and the other fluids of the system.

(6) The internal work of growth, maintenance, reconstruction and repair.

(7) The internal work of the automatic system regulating the functions and movements of the various organs, both external and internal.

(8) The internal work of conscious direction of the movements of body and limbs, and, in some cases, of internal organs, and, to some extent, of the work of respiration and of circulation.

(9) The internal work of the brain, and possibly of other organs, in the performance of conscious thought and of brain-work, a large part of which is essential to the proper performance of the useful work of the vital prime motor, and in the case of the man whose duties are those, distinctively, of the thinker, a large part of which must be rated as useful and prescribed work, determining the efficiency of the machine.

(10) Peculiar and characteristic forms of energy which are the special produce of some organism or class of organisms, and not essential elements of its operation as a vital machine, but which are employed occasionally as the special provocation to which they respond comes into action.

Such is the internal work last mentioned—that of the brain—where it is not the useful product of the machine; such is the energy expended in the production of the poison of the serpent, the secretion of offensively odorous fluids in many animals and, perhaps, the honey-producing glands of the bee may be thus classed. The most remarkable, and, in this connection most important, illustrations of this class, are found in the generation and use of the electric fluid by the torpedo and gymnotus and the production of light by the glow-worm and fire-fly.

Hybernating animals exhibit a peculiar modification of the action of the vital functions; their whole purpose, during hybernation, being to insure of the continuance of the physical operations of circulation and respiration by the employment of the previously stored energy of the accumu-

lated fat of the body. Very little tissue is wasted or repaired and the whole system is simply preserved in action through a period of temporary suspense of the life of the creature. That this may be done by the employment of pure hydrocarbons indicates that only energy and not material is required, for no nitrogenous aliment is absorbed or assimilated.

The measure of these various quantities of energy, useful and wasted, necessary or incidental to the purpose of the existence of a machine or its application to useful work, is, in the case of the external useful work of a laboring man or animal, easily and accurately made; but all the other items are very difficult, and usually, at present, at least, impossible, of more than approximate measurement, even if any clue can be obtained at all to their methods of action or their absolute and relative quantities. We have not yet discovered the nature of the primary methods of transformation of the energies imported, as latent, into the system, or even what energies are active in the production of the work of the brain and nervous systems and in the automatic operation of the machine. We know enough, however, to prove that the animal machine is a motor of very high efficiency as compared with the prime movers devised by man, (his thermodynamic engines, at least,) and to indicate, if not to prove, that the machine is a thermo-electric, chemico-dynamic, electro-dynamic or chemico-electric apparatus, or else a prime mover in which some unknown form of energy, acting by as yet undiscovered methods, is transformed more economically than in any case familiar to the man of science or the engineer of our time.

The power of animal machines varies greatly with the race and work. Investigations of the quantity of work per pound of the animal machine have been made by the students of aviation, which throw some light upon the problem in hand.* Thus Dr. Smyth measured the lifting power of a pigeon, as registered by a dynamometer, and computed its expenditure at 160 foot-pounds per pound of bird, or about 200 pounds

*"Progress in Flying Machines." O. Chanute, p. 39.

weight of bird per horse-power. Alexander computes 270 foot-pounds per pound, 120 pounds weight per horse-power. Penaud finds the following, which are thought to be more exact figures:

	Pounds per horse-power.
Peacock	66
Pigeon	57
Sparrow	48
Seapie	26

Were the weight of the pectoral muscles, which actually perform all this work, made the basis of these calculations, these figures would range from thirteen to about five pounds only per horse-power, thus giving the limiting weight of motor machine. The actual work of rising in the last cases is greater by the amount of slip in the wings, and the bird computed to give sixty pounds per horse-power is more nearly twenty pounds, and the last given figure becomes more nearly five to two pounds than thirteen to five. In full flight, the demand for power is much reduced, and becomes probably 500 foot-pounds per pound, or at the rate of 0·015 horse-power per pound, sixty-six pounds of bird per horse-power. This flying machine is proportioned to give the higher power at starting, the lower in steady working. Their emergency performance is thus probably three or four times the average for the day's work. This is also a fact illustrated in common experience with men, who, developing one-eighth of a horse-power for an average day's work, can exert a half horse-power for two or three minutes, a full horse-power for a few seconds. The aggregate power of the machine varies from an indefinitely small quantity with the smaller creatures, to 140 horse-power, as estimated for the whale swimming ten knots an hour.

The heart is, perhaps, the most powerful and enduring of all the muscular structures of the system. Helmholtz has computed that this organ can, on the average, raise its weight at the rate of 6,670 meters per hour. He found that the locomotive, climbing heavy gradients, in the cases investigated by him, at that time, could rise 800 meters in the hour, unloaded. He, therefore, concluded that the heart,

considered as a machine, was eight times as effective as the locomotive. Presuming that his locomotive had an efficiency of ten per cent., this would make the heart, were it self-contained and a prime motor, exhibit an efficiency of energy-conversion of about eighty per cent. This supposition is however by no means correct.

Fick estimates the efficiency of energy-transformation in the useful work of the muscle at one-third to one-quarter, the remainder of the total energy supplied being consumed in internal work and wasted directly or indirectly as heat.*

Chauveau points out the fact that the efficiency of the muscle varies enormously with time and method of contraction and extension and magnitude of load. In the case of the muscles of the automatic- the vital-system, as those of the heart and lungs and digestive organs, it is probable that the conditions are those of constant maximum efficiency, and the figure attained would seem, from other considerations, to be likely to be found comparatively large, and, for the machine as an energy-transformer, immensely greater than is ever attained in non-vital motors of the thermodynamic class. The energy-transformation is presumably never thermodynamic, but is, directly or indirectly, dynamo-thermic and the heat of the muscular system is a product, not a source, of useful work, and an excretion, not a food.†

It has been seen that the food required by the average workingman contains about 12,000 B.T.U. of energy when resting or doing little work, and about 16,000 when at hard work. It would thus appear that the work of the laborer, for which he is paid, represents about twenty-five per cent. of all the energy expended by the vital machine in external and internal work, heat-producing and wastes. This means that it performs one-fifth of a horse-power of commercially valuable labor, and, assuming all work concentrated into the working day, three-fifths of one horse-power, mainly, in the work of the organism itself.

A day's work, even for the average workman of full working power, varies greatly with the nature of the work and

* Experimenteller Beitrag. 1869. Ueber die Wärmeentwicklung. 1878.

† Chauveau : Travail Musculaire, pp. 233.

the method and facilities of its performance, and the same is true of the horse and all other animals, but usually in less degree. The most powerful horses may be expected to develop, as an average, two-thirds of a horse-power for eight hours a day, or 12,000,000 foot-pounds per day, very nearly, under favorable circumstances. The work of a man is variously given by different writers, but it is usually stated to be not far, *at best*, from 2,000,000 foot-pounds per day in the tread-mill, ascending mountains and stairways when his own weight is the useful load, and carrying burdens on a level. Weisbach gives as maximum figures 1,935,360. Rankine gives 2,088,000, while Ruhlman states the work of a Prussian soldier, carrying a knapsack and other accoutrements weighing a total of 64 pounds, as about 3,000,000 foot-pounds. We may safely take 2,000,000 foot-pounds per day as a figure to be compared with the 10,000,000 foot-pounds of energy supplied, and as giving a fair maximum for the efficiency of the animal considered as a prime motor.* It is 0·125 horse-power for eight hours, 0·04 for the day.

The efficiency of the animal machine, as an apparatus for the performance simply, of external work, is, on the basis here taken,

$$E = 2,000,000 \ / \ 10,000,000 = 0{\cdot}20,$$

twenty per cent. This happens to be just the efficiency of the best recorded steam engine performance to date.

The efficiency of the vital machine, considered as a motor, is high: Haller, about 1840, had applied the then new principles of thermodynamics to the action of the vital elements of the system, and had suggested that the heat of the body was, at least in part, due to the friction of the circulation. Joule found, by experiment, that the passage of fluids through tubes gave rise to heat and gave the correct explanation, as early as 1843. In the now famous paper of Joule, dated 1846,† he concludes:

The duty of a Daniell battery, per grain of zinc, is 80

* The Animal as a Prime Motor. R. H. Thurston Sec. 17, p. 50; Sec. 18, p. 53.

† *Philosophical Magazine*, 1846. Memoir of Joule, by Osborne Reynold, 1892, p. 100.

pounds raised one foot high—about one-half the theoretical duty—*i. e.*, its efficiency is about 0·50.

The duty of a Cornish engine, per grain of coal, is 143 pounds raised one foot high, an efficiency of 0·10.

The duty of a horse, per grain of food, is 143 pounds raised one foot high, "which is one quarter the energy due its combustion," an efficiency of 0·25.

Joule thus, at the middle of the century, had found the animal, taken as a prime mover, to be two and a half times as efficient as the best engines of his day, one and a quarter times as efficient as the best engines of our day, the close of the nineteenth century.

This figure is corroborated by many independent experiments and computations. Joule, as above, put the work of horse and man at about one-fourth, sometimes as low as one-sixth, the dynamic equivalent of the food-supply. Hirn found substantially the same figure as is above deduced, by measuring the work and the exhalations of carbon-dioxide and of moisture by his enclosed tread-mill operators. Helmholtz deduced 20 per cent., also, from the same experiments. Joufret takes the work of the man at 280,000 kilogrammeters and obtains 21 per cent., by the day, rising to 37 per cent., short intervals and actual expenditures of energy and proportional supply being taken.

We may thus, without much doubt, conclude:

The efficiency of the animal machine, assuming that only external, so-called useful work is reckoned as the product, and the full dynamic equivalent of the energy latent in the food-supply being taken as unity, is about 20 per cent.* Hirn's experiments with his enclosed tread-mill gave efficiencies from 17 to 25 per cent., the lowest being given by "a lymphatic youth of eighteen," the highest by a strong laborer of the age of forty-seven. The average is precisely that computed by the method pursued above.†

Our computation, however, should be checked by the introduction of the quantity of rejected, unassimilated food,

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* The Animal as a Prime Motor.

† *Ibidem*, p. 43.

if we are to learn the real maximum possible efficiency of the animal machine motor.

The factor of digestibility is probably with the animal machine, human or other, when in good health and normal, between 75 and 90 per cent., averaging not far from 80 or 85 with the customary healthful foods. With domestic animals, Professor Woods finds this factor to range all the way from about 50 to approximately 90 per cent.* This is confirmed by many other investigators, and the assumption of 85 per cent. as a fair maximum is probably perfectly justifiable, with all the familiar forms of the vital machine in good order.

In the case of Weston, the pedestrian—studied by Dr. Flint—the proportion of food utilized being taken as measured by the ratio of nitrogen absorbed in food to that excreted in chemically different combinations, the efficiency of nutrition, the "factor of digestibility," in one sense, was, when quietly training without excessive exertion and with very moderate exercise, and as an average for five days, 86·6 per cent.† It is probable that a good digestion and assimilation should be expected to attain an efficiency of 90 per cent., and that 10 per cent. of the food, or less, might be expected to be wholly wasted. Very nearly this efficiency was attained by the same individual during five days of recuperation after a five days' walk of 317·5 miles.

The food of the human prime motor has been seen to yield from about 2,500 calories, 10,000 B.T.U., 7,800,000 foot-pounds, nearly, when doing little or no work, up to 4,000 calories, 16,000 B.T.U., 12,500,000 foot-pounds, nearly, when doing a maximum day's work. This would seem to indicate that the internal work of brain, nerves, muscles and other organs of work and thought and heat production, must be about three times the total external work of a working day, and this, in turn, would again make the efficiency of the vital machine one-quarter, 25 per cent., corresponding once more to the maximum given by Hirn's direct experiments.

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* Reports of Conn. Agricultural Experiment Station.

† "Muscular Power, p. 84.

Reviewing what has been thus far collated, it will probably be admitted that the following may be taken as a fair estimate of the efficiency and energy distribution of the average representative human prime motor, assuming 10,000,000 foot-pounds supplied and 85 per cent. of the food to be digested:

THE ANIMAL MACHINE.

RECEIPTS AND EXPENDITURES—EFFICIENCIES.

Received Food-content.		Energy Utilized.	Per Cent. of Energy Available.	
Total receipts (foot-pounds)	10,000,000			
Loss, unassimilated	1,500,000			
Available and utilized		8,500,000	85·0	100
One day's labor, maximum		2,000,000	23·5	20
Heat rejected*		3,700,000	43·5	37
Thought-energy		500,000	5·9	5
Internal work other than friction		2,300,000	27·1	23
Wastes by non-assimilation, as above				15
Total		8,500,000	100·0	100

* Dalton.

Where the machine is a *thought-machine*, and not primarily a prime motor, the efficiency may be quite different, as will be seen later.

The wasted energy of the vital machine, when considered merely as a work-producer in the ordinary sense of that term, consists of the various internal energies expended in the operation of the machine, the misapplied mechanical energy of the twenty-four hours, and the heat radiated and conducted from the body and exhaled from the lungs. Could all these wastes be suppressed, the efficiency of the machine would be unity as a prime motor. Precisely what are these energies and their respective amounts is, as yet, unknown; their aggregate has been seen to be 80 per cent. To what extent either or all may be suppressed, as our knowledge of the machine enables us to employ it more and more intelligently, no one can yet say, except that it is known that the losses of heat from the exterior of the body may be kept down to a comparatively small amount, and, if necessary, made minute, by properly clothing it in non-conducting

materials, precisely as nature clothes the birds and the other wild creatures. If the suppression of this loss results in corresponding increase in energy-conversion, in useful directions, the efficiency of the machine is to that extent exalted. It is certain that some loss of heat externally is necessary to preserve the activities of organs of the body, by giving a needed difference of temperature between the surface and the interior, and to carry away energy in its final, thermal form; and mankind has, from the beginning, sought to reduce this waste by covering the body with skins, woven tissues, and other forms of material fitted to check the outflow.

The source of animal warmth and heat energy has been, for generations, the subject of study and experimental research by the best physicists and biologists. According to Jamin, Messrs. Halles and Cigna and Black and Priestley, showed that the products of respiration were chemically identical with those of combustion. Lavoisier confirmed this conclusion, and proved that the oxygen inhaled was not all accounted for by the exhalation of carbon-dioxide, but a balance must be sought in the production of water, by union with hydrogen. He attributed the vital functions to the oxidation occurring in the lungs, and circulation to digestion and to the regulating action of transpiration. Regnault and Reiset, measuring the volumes of carbonic acid produced, found that the larger the proportion of vegetable food, the greater the amount of this oxidation; while the combination of oxygen directly with the carbon of the nutriment sometimes gave an item in the balance of the account, its rejection occurring with the fluids of the system, as in uric acid, this proportion being the greater as the food was, in larger part, flesh. They found a small amount of nitrogen passing off, presumably rejected from the disintegrating tissues. Boussingault reached the same conclusions by determining the quantities of solid and liquid taken into the body and rejected from it. Lagrange, Spallanzani, Edwards and Magnus ascertained that the oxidation occurs in the circulation and the capillaries. Despretz and Dulong found the heat produced by the vital apparatus

to be about nine-tenths the quantity which would result from complete oxidation, in equal amount, in the air.*

The source of vital and muscular energy is easily identified, and it is well known that the function of digestion is to render available the potential energy of the foods by reducing them to solution in fluids capable of easily and rapidly and completely entering the constitution of the blood, to be distributed to points in the system at which their stores of potential energy may be made available in kinetic form. Precisely how this latter operation of transformation occurs is still unknown; but Claude Bernard, about the middle of the century, called attention to the action of the hepatic system in the production of glycogenic matter, and later investigation has shown that glycosic matter is distributed throughout the animal system from the liver and through the circulatory system into the capillaries, where it largely disappears and carbon-dioxide comes into view. It is now well understood that the oxidations and the energy-transformations essential to animal life and activities occur through reactions between the oxygen in solution in the blood of the arteries and the combustible elements accompanying it, which chemical operations take place in the depths of the tissue cells, and, perhaps, in the capillary vessels. It is also now admitted that the quantity of action is probably proportional to the loss of sugar and of oxygen, and to carbonic acid replacing the lost glycose as a product of its oxidation.† Since these chemical combinations are invariably low-temperature combustions, and since they are vastly greater in quantity in the active than in the passive muscle, and since the heat ultimately derived is the *excretum* of the system and the final result of energy-transformation, it may fairly be concluded that an intermediate transformation, or series of transformations, as yet unidentified, either qualitatively or quantitatively, constitutes the physiological method of production of work. Glycosic substance is not found concentrated in any considera-

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* An interesting corroboration of recent measures of the "coëfficient of digestion."

† See Chauveau and Kaufmann. Comptes rendus, t.ciii, 1886.

ble quantity in the tissues, except in the liver, the organ in which it originates, and the only conclusion would seem to be, that glycogenesis is the one extremity of a chain of transformations, of which heat constitutes the other. In this sense the hepatic gland is the source of muscular power, as well as of animal heat. It is this fact which makes the flow of blood to the working part, and the volume of its channels, measures of the energy there applied.* The weight of blood flowing through a muscle at work was found by Chauveau and Kaufmann to be about eighty-five per cent. of the weight of the muscle itself, each minute of working time, for full load. Its amount varies with the work performed, external and internal. The circulation, with the muscle in repose, was found, by the same investigators, to be about one-fifth as great as when in full work. The succession of changes is thus, probably, as follows:

(1) Potential energy in foods is rendered available as a source of kinetic energy by change of the foods into the various constituents of the blood by chemical action and the expenditure of some probably small net amount of chemical energy.

(2) This available potential energy is transferred to the capillaries by the blood, and its elements are selected by each organ for its own special development of mechanical work or of other and active energies.

(3) Chemical combinations take place, resulting in the production of active forms of energy, applicable to the special work of the organ, as mechanical work in the muscle, chemical action of characteristic kinds in the glands, nerve-power in the nervous system, and the accessories of thought in the brain.

(4) The internal energies, though useful, objective forms, each being utilized in the performance of its special work, are subject to a final transformation, and are at last converted into heat, and passed outward to be excreted by the skin and the lungs.

The latest researches indicate very positively that the

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* Chauveau and Kaufmann. Comptes rendus, t.civ. 1887.

production of heat in the vital prime mover is partly due to nutrition and tissue repair, or rather its breaking down, and not all necessarily derived from the simple and direct oxidation of the combustible matter of food. It is even uncertain whether the potential energy of food considered as a fuel, and of its combustion in air, is to be taken as precisely measuring its energy available for the work of the vital machine. Chauveau considers the glycogenic product of the liver, distributed to the tissues, the source of all mechanical and thermal energy. The sound animal machine can work vigorously about eight hours a day; the remaining sixteen hours are devoted to repair, reconstruction and energy-storage. Eight hours each day, one-third of life, is given especially to the reparation of the brain and mental powers.

Dr. Edward Smith has shown, by experiment upon himself, that the inspiration of air and the production of carbon-dioxide may vary in the proportion of one to ten, accordingly as the individual lies sleeping or actively exerts himself in the tread-mill or in running at top speed, the exhalations of CO_2 ranging from 5·5 grains to forty-five grains per minute.* The quantity becomes, for the given case, six grains when standing, twenty when walking, and twenty-five or thirty when walking rapidly. The variation seems to be approximately, in Smith's tables, as the square root of the speed of the pedestrian. Since the total work of the machine must vary as the velocity of overcoming a fixed resistance, as the cube of velocity where the resistance increases with the speed-square, as is here presumably the fact, it would seem from these facts that the interior resistance must be a rapidly increasing proportion of the total work performed, internally and externally, a deduction which is confirmed by constant and familiar experience. The experiments of the same investigator, however, seem to prove the variation of the exhalations when at rest, directly with the difference between the external and the internal temperatures; which, if corroborated fully, would indicate the heat of oxidation in the body to be ordinarily employed

* "Foods." International Series. New York: D. Appleton & Co.

principally in the maintenance of its warmth at the standard point. This makes it advisable to ascertain more exactly what energy is measured by the chemical actions resulting in the production of other rejected compounds, solid and liquid, and to learn, if possible, whether chemical action in one case produces the demanded thermal energy, and in others the required chemical or other motive energy.

These various deductions indicate that one-tenth or thereabouts of the energy of oxidation in the tissues of the body and in its capillaries finally produces work of various kinds; that nine-tenths passes as heat; that the efficiency of energy-conversion is thus ten per cent. On the other hand, the fact that external work alone gives transformation of twenty per cent. shows that both internal and external work must find ultimate conversion into heat from some other and antecedent form of energy of food-conversion and chemical action.

Rejected heat-energy increases rapidly with increase in the amount of work performed by the machine, and this seems to confirm the idea that the expenditure of internal energy in the accelerated operations of circulation, respiration and nutrition, must find ultimate conversion into heat and rejection in that form. The disappearance of thermal energy observed by Hirn is proof of this action. Hirn also found that the total heat exhaled exceeded by one-third that computed, and thus proved that it must be derived, in part at least, from other processes than combustion. The quantity was five calories, when resting, about half as much when at hard work, per gram of oxygen inhaled. Mental effort and work have precisely the effect of manual labor in this increase of the heat-waste and conversion of energy. The source of energy as an effect of oxidation would seem to be the food taken into the system and the broken-down tissues of muscle, bone and nerve, while the office of the food-supply is to replace this tissue, and to furnish the energy of chemical action as well.

Dalton* and others take the heat-waste of the human

* "Human Physiology," Philadelphia, 1875, p. 302.

machine as about 200 B.T.U. per hour, 1·28 B.T.U. per pound, nearly, or a total for the day of 4,800 B.T.U., equivalent to 3,734,400 foot-pounds. Assuming the possibility of complete suppression of this *as waste*, or what is equivalent to the same thing, its application to internal work of equal value with the energy applied to useful external work, the efficiency of the animal machine becomes

$$5,734,400 \div 10,000,000 = 0{\cdot}57 +;$$

over fifty-seven per cent., and exceeds that of any known form of thermodynamic machine in actual use, nearly three to one.

Whether the suppression of this waste, with corresponding gain in useful conversion of energy, can be effected, remains uncertain, and is perhaps unlikely to be practicable, although animals and human races in the tropics often live for long periods in temperatures at which no conduction or radiation of heat is possible and must depend entirely upon evaporation of moisture from the exterior of the body for its distribution. Since it certainly, in part, at least, represents the re-transformed energy of internal work, it would seem probable that only by effecting a balance between internal and external work of that class could this waste be completely suppressed. This is probably impossible with the vital engine, but nothing is known that would indicate similar necessary limitations in any artificial machine in which the essential transformations of the vital machine may in some way, possibly, be illustrated.

As has elsewhere been suggested, it seems certain that all the internal operations of the body, all the various methods of energy-transformation, must result in final reduction of their resultant total to the form of heat-energy, and, in that form, they pass away from the system. This conclusion is confirmed by the experiments of Rubner, who finds that the radiated heat of the animal body precisely measures the calorific power of the food utilized by assimilation.*

The internal work of the vital machine, as now computed,

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* *Zeitschrift für Biologie*, xxx, 1893, p. 73.

amounts to forty-three per cent. of the energy supplied, less the amount of rejected potential energy of unassimilated food. Neither quantity has as yet been precisely determined. Estimates have been made, however, and possibly sufficiently approximate for present purposes.

Letheby, for example, proposes the following for an average day of the average workingman at his usual vocations involving some manual labor:

Foot-pounds, external work, actual labor	1,011,670
Work of the circulation	500,040
Work of respiration	98,496
Total foot-pounds	1,610,206

Adding to this probably very rough estimate the 3,734,400 — 598,536 = 3,135,864 for heat not due to these causes, we have a total of 4,746,070 foot-pounds, or about one-half of all the energy supplied. Reckoning the work, as before, at 2,000,000 foot-pounds, the total becomes five-eighths the energy-supply.

This leaves, at least, three-eighths to be accounted for, and if we may take the proportion of blood taken to the brain as a measure of its demand for energy, and, as estimated by Flint, at about ten per cent., we still have about twenty-five per cent. as unaccounted for. But it is certain that a part, perhaps a large part, of the heat rejected from the system comes of internal fluid friction and energy-transformations, and it is also certain that some of the food escapes digestion and assimilation. In fact, the loss in the latter form of supplied energy has been computed, in some cases, as fully twenty-five per cent.

It would thus appear possible, if not extremely probable, that the full amount of the potential energy of the food actually assimilated may be accounted for in one or another form of the resultant energies visible or sensible as external, and as essential internal, work in the vital machine. Just what internal work the external heat-flow may represent, it is impossible to say positively; but, assuming that all the energy expended in the circulation of the fluids of the body, all the work of friction, so appears, and that all

energy of internal mechanical work of other sorts, and of all chemical processes occurring within the system, also, is thus rejected as heat; and assuming that the energy of brain and nerve action is transformed into mental and unmeasurable energies of which we have no dynamic equivalent yet established, the animal machine, as represented by the human body, may be taken as having an efficiency measured by the ratio of the sum of useful muscular labor and brain-work to the energy supplied.

This is now seen to be probably not far from thirty per cent., and the machine is, thus viewed, one and a half times as efficient as any existing steam engine.

If the use of the machine may be taken to be the production of muscle and brain-work, and of the heat required for the comfort of the system considered as an intelligent creature, the efficiency becomes the sum of these three quantities, divided by the total receipts of energy, or substantially two-thirds, the only waste, on this basis, being that of unassimilated food, and the energy of formation of chemical compounds, of heat, and of dynamic energy, unutilized, in a comparatively small proportion.

Brain-work is the task, and thought the product, of the professional man. The mass and weight of the brain give us some interesting data for consideration, if not throwing important light upon the problem in hand. The average weight of the brain of a man is about three pounds, perhaps fifty ounces; that of the average woman is ten per cent. less, about 45 ounces. High brain-weights are 53·4 ounces, the weight of that of Agassiz, up to 64·5, that of Cuvier; while low weights are indicative of reduced working power, if not of capacity for intellectual action. It is, however, true that the largest brains have been those of the idiotic and the insane, and that the greatest genius sometimes possesses a brain of but average size or even somewhat less; yet insanity and idiocy only prove, in most cases, disease of the ordinary brain of whatever size, and individual cases afford no evidence *pro* or *con*. The important fact is that size of brain increases with the intelligence of the race, and that, when the weight falls below about two pounds, two-

thirds the average for our own race, intelligence is usually lacking. Cerebration only occurs, efficiently, with larger proportions of gray matter.

The average weight of the male brain in African races is about that of females of the European races, and that of their females is ten per cent. lower. The weights in Australian races fall to that of the African female in the case of the male, and ten per cent below this for the female, or thirty-nine ounces. The weight never exceds fifty-five ounces except among the most civilized races. The bodily functions may be maintained and manual labor performed with very low weights, as healthy idiots have been known having brains weighing less than a pound, (8·5 to 10·6 ounces). The cerebrum constitutes eighty-seven per cent. of the cranial contents.

The compactness and firmness of the brain substance and the comparatively small quantity of blood with which it is saturated, in its ordinary healthy condition, indicate, probably, a slow building of tissue and construction of the gray matter constituting the brain material proper, and is, perhaps, also to be taken as evidence that the organ is not, like the muscles, in the opinion of many physiologists operative by the destruction of its own substance. The proportion of nutriment, suitable for each organ, presented by the blood, varies considerably, and it may be the fact that, for this reason, at least, the volume of blood sent to the brain is not a gauge of the energy supplied it in that form; but the probably slow construction of the tissue of that organ, and the comparatively small proportion of nerve and brain-making elements in the blood, are in accord with the hypothesis that some approximation to the ratio sought may be thus obtained.

The proportion of blood flowing to the brain would make it appear that about fifteen per cent. of the potential energy supplied the body is expended in brain-work. The fact that a loss of one-third the average weight results in loss of power of cerebration, possibly indicates that one-third the brain-power is devoted, in civilized races, to intellectual work. The fact that life and bodily health may persist with one-

third the average allowance of brain would seem to show that one-third the normal brain-action may be required for the conduct of the purely animal operations of the system. The corollary of these two deductions would seem to be that the normal thinker expends one-third his brain-power upon the vital machine, one-third upon the incidental and accidental cerebrations of life, and one-third upon real, purely intellectual work. But the size of brain and its quality are both known to be factors in the determination of the magnitude and nature of its product intellectually, and it is very possible, probable indeed, that the intellectual mind, with a brain well adapted to its use, not only has an instrument capable of doing more and better work than the average- but makes more use of that instrument than does its neigh, bor of equal brain weight. It is for this reason, in part, that the figures here assigned for brain-work have been fixed upon. As a matter of simple proportion, the human machine, acting as a prime mover simply, develops from 1,000,000 to 2,000,000 foot-pounds of work per day. The best worker is, usually, also most intelligent, and, following the above suggestion, it may, perhaps, be assumed, in default of direct measurement, that the "brainless" worker —using that term in its vulgar acceptation—may perform the lesser amount, 1,000,000 foot-pounds, and that the intelligent worker may, under similar external conditions, produce 2,000,000 foot-pounds, and that the latter may use his brain and consume energy supplied by the average brain, in moderate amount as well. If the professional brain-worker does less physical labor and more brain work, he may substitute the one for the other, to a considerable extent, and we have assumed 1,000,000 foot-pounds as the measure of a brain-worker's day's work, in addition to the labor of carrying on the bodily functions and that of regular, moderate exercise. As yet, however, such figures are little better than guesses.

The efficiency of the thought-machine, as the "brain-worker" of modern times has become, cannot be estimated with even so much of accuracy and certainty as that of the same organism employed as a vital prime motor and mechanical

engine. The considerations presented in the last section and in some of the earlier portions of this discussion would seem to indicate that the energy demanded by the brain for transformation, presumably, in the operation of the apparatus as the instrument of the mind and the tool of thought, may be fairly taken as between five per cent. for the case of the workingman giving all his energies to his task, with little time and no strength for mental labor, and for the non-intellectual creatures most nearly approaching man in their constitution and structure, and ten per cent. for the average intellectual product of civilization, up to perhaps fifteen per cent. in the case of the steadily working professional brain-worker. This is mainly to be deducted from the energy applied by the laborer with his muscles to his daily task, and the efficiency account would, in such case, stand as a first and a rough approximation, perhaps, as follows:

THE INTELLECTUAL MACHINE.

RECEIPTS AND EXPENDITURES—EFFICIENCIES.

Received Food-content.		Energy Utilized.	Per Cent. of Energy Available.	
Total receipts (foot-pounds)	8,500,000			
Waste, non-assimilation	1,500,000			
Available and applied		7,000,000	82	100
One day's work (thought)		1,000,000	12	14
Heat rejected		3,000,000	35	43
Internal work, aside from friction		2,000,000	23	29
External work (moderate exercise)		1,000,000	12	14

This estimate makes the efficiency of the mental machine fourteen per cent. if based upon the energy actually offered it in the circulatory system, or twelve per cent. if based upon the total food supply. If the exercise taken can be made also commercially useful, the efficiency, on this assumption, becomes twenty-eight or twenty-four per cent., and if the essential work of the machine is taken as that of providing its operator with heat and brain-power it becomes fifty-seven or forty-seven per cent.; the internal work as here denominated being the only waste except that of non-assimilation of food.

Whatever may be taken as the proper method of reckon-

ing efficiencies from the utilitarian standpoint, it is obvious that, in one form or another, the machine—this vital engine—converts eighty or ninety per cent. of the energy received by it into new energies by transformation; and, taking the real waste in the scientific sense as that of the heat rejected, the efficiency for comparison with heat engines—in which but one purpose exists, that of providing a single form of energy, transforming all received into the mechanical form, so far as practicable—it is fair to say that the former, with its efficiency as thus stated at fifty-seven to sixty-five per cent., excels the perfect heat engine of our time enormously, has twice the highest theoretical efficiency of the best steam engine yet produced, and three times its actual efficiency under the most favorable conditions yet reported. To attain this efficiency of the vital machine, any heat engine acting under the laws of thermodynamics, *as applied to motors with fluid working substances*, the only forms as yet devised, must, if we take the temperature of the human body as its minimum, have a range of about 375° F., and a maximum temperature of about 475° F. These should be the limiting temperatures of the machine, if it were a thermodynamic engine operating under any such conditions as are now known to limit the action of the heat engines.

The maximum possible range of temperature in a mass of organic substance, of which fifty per cent., or more, is water, and the circulating fluid mainly a solution of organic substance, cannot possibly be much greater than the range between the freezing and boiling points of pure water. But the efficiency of the best heat engine known, even acting as a perfect thermodynamic engine, would not exceed the ratio $180/672 = 0{\cdot}27$, twenty-seven per cent., and its actual efficiency would probably fall below twenty per cent. The animal, the vital engine, certainly has *no* sensible range of working temperature, and no elastic working substance like the gases and vapors; but its efficiency, even as a work-producer alone, exceeds the above figure, and, as an energy-producer, its efficiency exceeds that of ordinary heat-engines several times.

The correct method of estimating the efficiency of the

vital machine is unquestionably that which sums up all its expenditures of energy, thermal, mechanical, mental, and determines the ratio of that sum of all energies so far as directly contributing to the purposes for which the dweller within the apparatus lives, with the total energy supplied during a period including at least one perfect cycle. Taken in this manner and in this sense, the rejected heat would seem to constitute the only real waste, and the efficiency of the machine, as a peripatetic residence for the soul, would seem to be fairly reckoned at not less than forty-five per cent. nor more than sixty-five, accordingly as one or the other of the units above taken are accepted—two to three times the maximum efficiency of the best-known heat engines.

The rejected heat-energy is precisely like that of the final heat-waste of the electric lighting system—the final form of energy subjected to transformations of greater or less complexity during the process of application, in some definitely demanded phase, to a prescribed purpose. Rejected heat is certainly not, in the case of the vital machine, "let down" from a higher temperature in the process of thermodynamic conversion, an essential characteristic of that form of prime mover. The machine is evidently not a thermodynamic engine.

[*To be concluded.*]

PART I—ERRATA.

THE ANIMAL AS A PRIME MOVER.

P. 10, line thirty-three, for "of" read "above;" p. 15, line twelve, for "cabbage, carrots," read "carrots and turnips.;" p. 18, note that engraver has transposed hatchings for protein and carbohydrates.

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,

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[*Concluded from p. 56.*]

Stereotomy is a species of advanced descriptive geometry, and can easily be acquired by any one who is familiar the latter subject. It bears more especially upon the work of the engineer who is to erect large buildings where stone plays an important part, or masonry bridges.

Of surveying and topographical drawing, of course, every engineer ought to have some knowledge, but the principles of surveying are easily learned by any one who has a scientific training and some skill in handling measuring instruments, and nicety of execution can only be acquired by long-continued practice, and the greater part of this practice will have to be acquired subsequently. Surveying has sometimes been assumed to be the principal business of the civil engineer, and frequently a man who was merely a surveyor has called himself a civil engineer; but the progress of the world is sweeping this away, and a man who is merely a surveyor is no longer considered to be an engineer any more than a machinist is an engineer. Now, while the man who is to build roads or railroads will probably have to use surveying to such an extent that it will be necessary to give him in the school more than is given in the other engineering courses, nevertheless his practice will have to be acquired subsequently, and the instruction in those things that he cannot acquire later, or can only acquire later with a great deal of difficulty, should, on no account, be sacrificed for surveying.

When we come to the higher geodetic work, we have geodesy, and not engineering and hence it will not be considered here. Then as to shopwork, very similar remarks

to those I have made in regard to surveying, will apply. It is something in which every engineer should have some practice, but which should not be given at the expense of more important engineering work. Indeed, it would be extremely desirable that this should be acquired at the manual training schools before beginning an engineering course, and whenever the manual training schools are established everywhere as a part of the public school system, so that young men who wish to take an engineering course at some engineering school can first attend the manual training school, then the engineering schools will not need to teach so much shopwork and what they do teach will be of a more advanced character.

Coming, now, to the studies of the second class, we shall find that we may divide them into two classes, the first being those requisite for such specialties as can be developed by a suitable addition of certain lines of work, but where these lines of work depend upon the previous training that has been given; and second, those where a considerable knowledge of, and hence a drill in, chemistry is necessary. Among the first I should place: (1) bridges; (2) hydraulic engineering; (3) railroad engineering, with special reference to permanent way; (4) railroad engineering, with special reference to motive power and rolling stock; (5) marine engineering; (6) mill engineering; (7) naval architecture; (8) electrical engineering; and others as they might arise.

In the second class, on the other hand, I should place mining, metallurgical and chemical engineering, and others as they might arise.

The essential difference between these two classes is that, in the latter, a considerable knowledge of chemistry is required, and, consequently, that the student must have considerable instruction in elementary chemistry and in qualitative and quantitative analysis, before he is in condition to discuss the subjects pertaining to his special line; and hence, that for these courses, a certain amount of chemistry becomes one of the essential fundamental studies that the student cannot do without, and must be provided for at the

start by assigning the necessary time for it in addition to that needed for the other fundamental studies. When suitable provision is made for this, there remains, of course, less time for other subjects than there is in the other cases.

Of course, the amount of chemistry required is a matter of degree. In some lines of mining engineering it is not great, whereas, in metallurgical works, or in chemical works, the amount is decidedly larger.

Nevertheless, the one who is laying out any of these courses must bear in mind that they are intended to fit men to do primarily the engineering work of such establishments, and that it is not necessary that they should have as much chemistry as would be required by the analytical chemist. Hence, he should begin by considering what is the minimum amount of chemistry which it will do to put in the course; put that in, and then leave the rest of the chemistry, which it might be desirable to add, to take its chances with the other professional subjects, according to their relative importance in the special line of work for which the course is laid out.

Let us assume, now, that we have fixed upon the fundamental subjects, and the time that must be given to each. We are prepared, then, to map out the course to be pursued in the second class, or special line of studies, including whatever of the first class we deem wisest to insert in the list.

Were I to attempt to map out the details of what should be given in the case of each special engineering course in these special lines, I should need a whole course of lectures to elaborate it. I shall only say a little, therefore, about some general rules to be observed in making the selection:

(1) To drill the student in all the details of his profession, or to impart to him experience, is not possible in a school. Experience can only be gained after the school days are past, and he goes to work.

(2) To attempt to perfect him in those things that he will have to do when he first goes to work, at the expense of his later success, is a very short-sighted policy.

(3) Hence, the object to be attained should be, first, to so

arrange this work that he shall have to deal with such cases as are liable to arise in the practice of his profession, as with the actual details of a bridge, of a steam engine, of a locomotive, of a mill, etc., and thus become familiar with what he is likely to meet later on; and secondly, that he shall be taught how to go to work on these problems in a scientific manner, applying the principles that he has previously learned, thus teaching him what is the relation of his scientific study to the practical problems he will meet later in life.

Next, in regard to the third class of subjects, or those intended for general information, it is desirable to insert as much as can be inserted, without sacrificing the accomplishment of the main objects of the course.

Such subjects are, mainly, linguistic and literary studies. The first, however, if confined to the modern languages, are also, to a certain extent, professional; for, without modern languages, some of our most valuable engineering literature is closed to the student.

Having thus marked out the character and the scope of the studies that should enter into an engineering course of one or of another kind, it remains for me to speak of two subjects, viz.: (1) The graduation thesis, and (2) the extent to which laboratory practice in the engineering laboratories should be introduced into the courses.

First, as to the graduation thesis. It has always been the custom for the engineering schools to require of the students, before they are graduated, a thesis. The special feature required of a thesis should be that it shall involve an element of original investigation, and its chief object is to teach the student how to make, and to give him practice in making, original investigation on his own account. He should be made to feel that the problem is his own to solve. He should be encouraged to propose his own plans for the solution, and to submit them to some one member of the corps of instruction, who should aid him when he needs aid, and exercise so close a supervision over his work, that he should be made to do it correctly.

If this supervision is properly maintained, a large

amount of investigation can be accomplished in connection with the thesis work.

In giving the instruction I have outlined above, it should not be merely class-room instruction, but also laboratory work, partly to emphasize and illustrate the work of the class-room, partly to drill the student in performing carefully and accurately such experimental engineering work as he is liable to be called upon to perform in the practice of his profession, and partly to teach him experimental investigation.

The student will have, of course, in addition to this, laboratory work in his special line, as in the mining laboratory, electrical laboratory, industrial chemistry, laboratory, etc., besides, of course, work in the chemical and physical laboratories.

I have previously called attention to the process of gradual development which has resulted in the extensive introduction of laboratory practice of a variety of kinds into technical instruction, and therefore to the evolution of the engineering laboratories.

As to the organization of such laboratories, the principal objects to be accomplished by them are three, to wit:

(1) To give the students practice in such experimental work as an engineer is constantly liable to be called upon to perform in the practice of his profession, as tests of the strength of materials, evaporative tests of steam boilers, steam engine tests, calorimetric tests, valve setting, etc.; and to teach him to carry on his work with accuracy, and to take all proper precautions to avoid error.

(2) To give the student opportunity of carrying on original investigation in the engineering branches, such as investigations in strength of materials, in steam engineering, etc.

(3) Another important function of such laboratories, which is entirely consistent with the other two, is that of taking up and carrying on systematic investigations of engineering problems, and this can be done in a laboratory, whereas it is only with very great difficulty that it can be

done in a machine shop or a manufacturing establishment.

By publishing these results from time to time the laboratory will serve to add gradually to the common stock of knowledge.

I recognize very fully the incapacity of the student, as a rule, to originate and carry on research without aid from his teachers; but when this aid is given, and the necessary supervision is exercised, a large amount of research can be accomplished in such laboratories.

Original researches should also be carried on by the students in connection with their graduating theses; some of them are, of course, better able to do this kind of work than others, but all should be required to undertake original research, and a careful supervision should be exercised by some one of the instructing force, who should see to it that whatever is done should be properly done, so that the results, as far as they go, whether extensive or not, may be of real value.

Inasmuch as the number of important investigations which it is possible to take up and carry out is so very large that only a few can be undertaken in any one laboratory, and, therefore, while there are certain pieces of apparatus of so typical and general a character that all engineering laboratories need them, and should be provided with the best that their means will admit of, as for instance, testing machines and steam engines—the remainder of the apparatus may vary very considerably in equally well-equipped engineering laboratories.

Instead, therefore, of laying down general rules for the equipment and conduct of such laboratories, it seems to me that I shall be better able to convey my ideas by describing to you the equipment of the engineering laboratories of the Massachusetts Institute of Technology, and the way in which they are conducted.

The first attempt at establishing engineering laboratories at the Institute was made in the school year 1873–74, when one was equipped with the following apparatus, viz.:

(*a*) Two horizontal tubular boilers, each 4 feet in diam-

eter and 12 feet long, containing fifty 3-inch tubes; (*b*) one small vertical tubular boiler, 3 feet in diameter, and 7 feet high, containing fifty 2-inch tubes; (*c*) a cast-iron superheater; (*d*) an 8-inch by 24-inch Harris-Corliss engine, with a brake on the fly-wheel; (*e*) a combined surface condenser and calorimeter with the necessary tanks and scales; (*f*) also a variety of accessory apparatus, as indicators, gauges, etc. From this laboratory there emanated an investigation into some special problems on cylinder condensation made for Mr. George B. Dixwell.

From these small beginnings, partly through gradual growth, and partly through considerable changes and improvements made all at one time, have arisen our present engineering laboratories, situated in the Engineering Building, and occupying two floors, 50 x 150 feet each.

The equipment of the Laboratory of Applied Mechanics, *i. e.*, the laboratory for testing the strength of materials, embraces the following apparatus:

(1) A testing machine of 300,000 pounds capacity, made by William Sellers & Company, Incorporated, under the patents of Albert H. Emery, the maker of the Government testing machine of 800,000 pounds capacity at Watertown Arsenal.

This machine has recently been added to the equipment of the laboratory, and it is to be observed that this style of testing machine is the most delicate and accurate in the world. Moreover, the amount of investigation in the line of strength of materials of such a character as to be of positive value to the engineer, which has been made by means of the Government machine at Watertown, is far greater than that which has been accomplished by means of any other testing machine in the world.

It is provided with suitable holders and measuring apparatus to adapt it to specimens of different shapes.

(2) An Olsen testing machine of 50,000 pounds capacity for determining tensile strength, elasticity and compressive strength.

This machine is furnished with compression platforms, which distribute the pressure evenly over the specimen.

(3) A testing machine of 100,000 pounds capacity for determining the transverse strength and stiffness of beams up to twenty-five feet in length. By means of this machine tests are also made on the strength of framing joints used in practice, and on the strength of the riveted joints of plate girders, as well as on other specimens subjected to transverse stress.

(4) A testing machine of 18,000 pounds capacity for determining the transverse strength and stiffness of beams up to fifteen feet in length.

(5) A machine of 144,000-inch pounds capacity for testing the torsional strength and stiffness of shafting up to twenty-one feet in length, provided with apparatus for measuring the angle of twist to four seconds of arc.

(6) A testing machine of 25,000 pounds capacity for determining the strength of ropes or wire, where the clear length of the specimen can be made as great as ten feet. By means of this machine tests are made upon both long and short splices, and on a variety of hitches and holders.

(7) A machine for testing the tensile strength of cements and mortars, where the clips have been specially designed in such a way as to secure an evenly distributed pull on the specimen. In connection with this machine is a complete outfit of nicely-constructed moulds for making the briquettes or specimens, and also all other necessary apparatus, as sieves, tanks, etc.

(8) A machine for determining the strength and elasticity of long specimens of wire.

(9) A machine for determining the strength and elasticity of cloth.

(10) A machine for determining the effect of repeated stresses on the strength and elasticity of iron and steel.

(11) A machine for determining the deflection of parallel rods when running under different conditions.

(12) A quantity of measuring and other apparatus for determining stretch, deflection and twist.

The students who take the subject of applied mechanics in their senior year are required to learn how to use this apparatus, and the method of making the different kinds of

tests, thus learning how tests should be made, and also acquiring a familiarity with the appearance and behavior of materials when subjected to stresses such as occur in practice.

Thus, in the school year each student makes the following tests in the laboratory:

(1) A test to determine the modulus of elasticity, the limit of elasticity, and tensile strength of a cast iron or wrought-iron or steel rod or bar, or the transverse strength of a coupling.

(2) A test of the deflections and of the transverse strength of a full-size iron or steel I beam, or of a wooden beam subjected to transverse load.

(3) A test to determine the modulus of elasticity and the tensile strength of various kinds of wire.

(4) A test to determine the shearing modulus of elasticity and the torsional strength of a shaft.

(5) Tests of the tensile strength of hydraulic cement.

(6) Tests of the compressive strength of hydraulic cement.

(7) Tests of the strength of rope, and the loss of efficiency due to different hitches and knots.

(8) Besides the above the students make a variety of tests of large pieces on the Emery testing machine; sometimes compression tests of full size columns, or of small blocks, or of columns with bolsters, etc., and sometimes tensile tests of pieces of varying shapes and sizes.

The hydraulic laboratory contains:

(1) A closed tank, 5 feet in diameter and 27 feet high, connected with a 10-inch stand-pipe over 70 feet high, so arranged that a constant head may be kept at any desired level.

(2) Apparatus in connection with the tank and stand-pipe, for making experiments on the flow of water through orifices and mouth-pieces, over weirs and in pipes, under different heads and conditions, and on the losses of head occurring under different circumstances.

(3) A system of pipes, connected both with the main pipe and with the pumps, is fitted for the insertion of diaphragms, branches and other apparatus for studying loss of head and the laws of discharge.

(4) An attachment to the main tank, containing a Pitot tube for studying the laws of velocity in jets, and adjustable points for the measurement of the cross-section of jets.

(5) A cylindrical steel measuring tank of 280 cubic feet capacity.

(6) A six-inch Swain turbine, so arranged that it can be run under different heads, and that measurements can be made of the power exerted, of the efficiency, etc., under different gates.

(7) A 48-inch Pelton water motor, similarly arranged.

(8) A Venturi meter and numerous hose nozzles for measuring water.

(9) A weir of adjustable width up to four feet.

(10) A hydraulic ram with a two and one-half inch drive pipe.

The steam laboratory contains:

(1) A triple-expansion engine, with cylinders of 9 inches 16 inches, and 24 inches diameter, respectively, by 30 inches stroke, arranged in such a way as to be run single, compound or triple, as desired for the purposes of experiment. It is of the Corliss type, and has a capacity of about 150 horse-power when running triple, with an initial pressure of 150 pounds in the high-pressure cylinder. To it is connected a surface condenser, and the other apparatus needed to adapt it to the purposes of accurate experiment.

The ends and barrels of the cylinders are separately jacketed, so that steam can be let into either or both. The receivers are also jacketed so that they can be used either with steam in the jackets or not. The cut-off on all three cylinders can be thrown into connection with the governor, or any of them can be disconnected from the governor and adjusted by hand at a fixed point. Cans are provided for catching the drip from each jacket, and these cans are provided with water-glasses so that we can determine its quantity.

The engine is thus fitted to carry on series of experiments under different conditions, and by its use we can obtain results comparable with the results that are actually realized on large marine and stationary engines. The water consump-

tion per horse-power per hour varies with the different conditions under which the engine is run, but we have found it under some conditions as low as 13·7 pounds.

A very considerable amount of investigation has been carried on already, and valuable results have been obtained.

(2) A Harris-Corliss engine, with cylinder 8 inches diameter by 24 inches stroke, with a capacity of about 16 horse-power, with an initial pressure of 75 pounds. This engine is also connected with a surface condenser and a tank on scales to weigh the condensed steam, and, of course, it can be used to make engine tests; but inasmuch as it is a small engine, it is not economical, using from 30 to 40 pounds of water per horse-power per hour; and, now that we have the triple expansion engine, we use the Harris-Corliss machine mainly for valve-setting. Moreover, this Harris-Corliss engine is the original one that was put in the laboratory when it was first founded, in 1873, by means of which the investigations were made for Mr. Dixwell.

There is also another eight-horse-power engine used for valve-setting, etc.

(3) Of surface condensers there are four in all: (*a*) the one connected with the triple-expansion engine, and which is also specially arranged for experimental purposes in such a way that the condensing water can be made to pass once, twice or three times the length of the condenser while performing its functions; (*b*) a smaller surface condenser attached to the Harris-Corliss engine, and (*c*) and (*d*) two other surface condensers, used in various experiments.

(4) A mercurial pressure column which extends to 160 pounds pressure, by means of which our gauges are tested. There is also a mercurial vacuum column.

(5) A dynamic steam engine indicator tester.

(6) Several pieces of apparatus for determining the quantity of steam issuing from a given orifice, or through a short tube, under a given difference of pressure.

(7) Apparatus for testing steam injectors.

(8) A number of steam pumps, the largest one being a duplex pump 16, 10½ by 12 inches.

(9) A number and variety of calorimeters.

(10) A large supply of indicators, planimeters, gauges, thermometers, anemometers and other accessory apparatus.

(11) There are in the different buildings two 208-horse-power sectional boilers, two 100-horse-power, and one eighty-horse-power horizontal tubular boilers, and another sixty-horse-power horizontal tubular boiler at the shops, and these are used for making boiler tests; all the fourth year students of mechanical, electrical, chemical engineering and naval architecture, having to take part in these tests.

It is believed that the students can best learn to make boiler tests by making them on large boilers producing a considerable quantity of steam.

Besides all the above, the engineering laboratories are provided with several friction brakes of different capacities; with machinery for determining the tension required in a belt to enable it to carry a given amount of power, at a given speed, with no more than a given amount of slip; with a machine for testing the transmission of power by ropes; with a number of transmission dynamometers; with a four-horse-power gas engine; with a complete set of Westinghouse air-brake apparatus, including the parts belonging to the car and to the locomotive; with the pump and engineer's valve of the New York air-brake; with a measuring tank for large quantities of water, this tank being provided with a number of orifices in the bottom, and a water glass on the side; with a number of water meters, and of weirs of different sizes, for measuring water; with a locomotive link model; with a centrifugal pump, a gang pump and a rotary pump; with a hot-air engine; with a pulsometer pump; with an experimental governor; with an oil-testing machine; with a number of water motors; with an ejector; and with cotton machinery as follows: two cards, a drawing frame, a speeder, a fly frame, a ring frame and a mule, as well as accessory apparatus. As to the work required of the students of mechanical, electrical and chemical engineering, I will say that in the second term of their junior year they are required to make, under careful supervision, engine tests on the triple engine. In the course of the senior year the list of tests made by each student is approximately as follows, viz.:

Tests of the transmission of power by belting; test of the performance of a surface condenser; test of a direct-acting steam pump; test of the flow of steam; valve setting (plain slide valve); test of a pulsometer; test of a plunger pump; calibration of orifices for the flow of water; determination of the clearance of an engine; use of the different dynamometers; valve setting (double valve); testing gauges by means of the mercury column; test of some of the boilers; test of the steam injector; test of steam ejectors; use of the different kinds of calorimeters; test of a Swain turbine; measurement of the flow of water by means of orifices and weirs; test of water motors; test of a hot-air engine; valve setting (Harris-Corliss engine); analysis of chimney gas; test of a battery of boilers application of Hirn's analysis to the triple-expansion engine in the laboratory; test of the efficiency of a Weston differential pulley block; test of the efficiency of jack screws (each test is performed by a squad of from two to five students, and the results are then worked up and handed in within two or three days by each member of the squad); test on experimental governor; tests on the indicator tester; tests on the gas engine; tests of water meters; calibration of hose nozzles, etc.

The tests are all made under such supervision as will insure accurate work, and reliable results.

Then each student is required to make all the calculations for every test in which he takes part, and to hand them in within a week.

These reports are examined by competent instructors who make all the calculations independently before examining those of the students.

Then each student is furnished with the results of all the tests in which he takes part, and, moreover, the results of the investigations made in the course of the regular laboratory work of the engineering laboratories is regularly published in the *Technology Quarterly*.

The above is a description of the equipment of, and the work done in, these laboratories at the Massachusetts Insti-

tute of Technology. It is plain that some of the most common work of the engineer in practice will be to make tests of steam engines and of steam boilers, to make tests of power and to determine quantities of water either in hydraulic work or in work on steam.

Now, the young engineer should be drilled in doing this work accurately and well, and should understand what constitutes good work; more especially is this of importance because there are so many so-called engineers who make tests carelessly and publish results which have been obtained from tests erroneously made. Too often they do not give a detailed description of how they made their tests. Before one can judge of the credibility of the results of a test, he needs to know how the test was made.

The student should be taught to do all that he does, well and thoroughly. It will be easy enough to teach him to do rough work when it is required if he knows how to do accurate work, but if he is accustomed to do rough work it will be very difficult to make him do accurate work.

WATER PURIFICATION.*

By Rudolph Hering.

The subject of the lecture which has been set down for to-night is one which might occupy our time for many evenings, even if it should be treated, in part, quite superficially. There are many aspects under which it might be considered, and, in order that it may possibly be of some value to you, it is necessary that we confine ourselves to but one aspect, and even this one we shall not be able to exhaust.

The use of water may be divided into three general classes—domestic, public and manufacturing. In the first class we place the water used for drinking, for cooking and for washing; the second class comprises the water used in

* A lecture delivered before the Franklin Institute, February 2, 1894.

fountains, for extinguishing fires, for street-cleaning, sewer flushing and the like; and the third, the water required for different industries.

It is evident, therefore, that the water supplied to a community for these various purposes might properly have different degrees of purity. The highest grade of purity is required for domestic purposes. If there is a sufficient quantity having this high quality available to supply all the uses to which water may be put in a city, so much the better; if such a source is limited, then we must avail ourselves of different supplies for the same city. Such is the case, for instance, in the cities of Paris and Vienna.

We shall confine ourselves, in the following, to water required for a domestic supply; namely, to that which should be pure in a sanitary sense, and which may be used for drinking, cooking, etc.

Such water should contain no foreign matter which is known to produce an injurious effect upon the human body, or which, with good reason, is suspected of producing such an effect, and it should be pleasant to the taste. It should also be, as far as practicable, free from all substances and associations which may offend the general æsthetic sense and affect the system through the imagination, even though the water itself be perfectly harmless.

We may therefore say that water which is suitable for domestic uses must be clear, cool, soft, without odor and with but a slight taste, neither stale, salty nor sweetish. It should have air in solution, it should contain but little foreign matter, and, most important of all, it should contain no pathogenic or sickness-producing microbes.

It may, with advantage, contain certain mineral salts, particularly a little lime, to supply nourishment for such parts of the body as require mineral matter. Among the salts of lime, the stomach takes more kindly to the carbonates than to the other compounds. Further, an excess of carbonic acid in drinking water aids the digestion of certain fluids which otherwise might be harmful; but, on the other hand, it is not desirable for cooking purposes. When drinking water has a disagreeable taste and a high temper-

ature, it will, as a rule, diminish the secretion of gastric juices and cause a poor digestion.

Water without air in solution may be quite harmless to drink, but in natural waters such absence may indicate other dangerous qualities, inasmuch as the air may have been absorbed by the decomposition of organic matter in the presence of dangerous microbes.

In water used for washing, salts of magnesia are objectionable, on account of the hardness which they produce. They also act as a laxative and are therefore debilitating. Hard water fatigues the intestines, and injures the assimilative processes by forming insoluble compounds with some food materials. Water containing an excess of salts may even counteract the digestive processes and favor hurtful molecular actions. All sulphates will generally lie heavily in the stomach. Nitrates are not injurious of themselves, but their presence in water may indicate a previous sewage pollution, and therefore a danger possibly still existing.

Finally, a water contaminated with organic matter may bring into the system microbes, or bacteria, and ferments, which interfere with the normal functions of the stomach and the intestines. After entering the body they may cause sickness to a more or less serious degree. Most dangerous of all is a pollution by those bacteria which are the cause of some of our most fatal diseases. Cholera bacilli, which were introduced into the drinking water of Hamburg, caused the late epidemic in that city, the most recent warning of the danger of such pollution. The epidemic of typhoid fever in Plymouth, Pa., some years ago, was caused by the introduction of typhoid bacilli from a single individual into the limpid waters of a mountain brook supplying a part of the city. Within a few weeks over 1,000 cases of typhoid fever occurred among the water-takers of that otherwise healthful town, and of these cases over 100 were fatal.

There are already on record so many cases showing the unmistakeable connection between the water of a domestic supply, polluted by certain species of bacteria, and the appearance, among the consumers of this water, of the

disease associated with such organisms, that it should now be considered almost criminal to ignore any practical means for obviating the recurrence of such calamities, and for maintaining a pure supply.

In addition to guarding the sources against pollution, we must also guard the water itself after it is in our midst. If pure spring water or ground water is brought to rest in an open reservoir exposed to light and warmth, living organisms rapidly develop therein. The atmosphere has supplied the germs, and warmth and light have caused them to multiply. A green scum covers the water, and later it is filled with algæ and bacteria, until the organic matter which serves as a food has been completely removed. River water, stored in a similar manner, is generally not so altered, because the conditions of storage are not materially different from those in the river, and there is no cause for a sudden change in the action of the bacteria. Therefore, when the water comes from springs or from underground sources, it must, to keep it pure, be stored in *covered* reservoirs.

But even this precaution does not always protect it, for it is difficult to preserve in all respects the same conditions which existed at the source. We have on record a case which well illustrates this. The supply of Monaco comes entirely from springs. At the covered reservoir it arrived with five microbes per cubic centimeter. After twenty-four hours there were several hundred, and after a week over three hundred thousand, or sixty thousand times as many as at first. After standing, the number of microbes decreased, until, being after six months in the same reservoir there were found to be but ninety-five per cubic centimeter.

This curious fact, that spring water when exposed to the atmosphere will cause a greater development of bacteria than river water, is noticed also in the relation between sterilized and non-sterilized water. In the former, when sterilized by boiling, it was found that typhoid bacilli continued to flourish vigorously for three months, while in the same water, which had not been boiled, they gradually disappeared.

Water brought to a city in a pure condition, or sterilized

at home, should therefore be used as soon as possible, and before it can receive fresh bacteria from the air.

Muddy water should not necessarily be condemned, if turbidity is its only objectionable feature. While a clear water, is of course, more desirable, a turbid source should not weigh against the adoption of one that is comparatively free from dangerous bacteria, for muddy water free from pathogenic or disease-producing microbes is far preferable to clear water containing them.

If much vegetable matter is contained in the water it may be unwholesome. Water from marshes is known to have caused intestinal derangements and probably also malarial and other fevers.

Animal matter produces a still more dangerous effect, and it is to-day believed that most of the zymotic diseases are caused indirectly by animal pollution of water supplies.

Water which contains organic matter, if left standing in a vessel in a warm place, gradually becomes turbid, and after a certain time a film may be seen on the surface, while deposits form on the sides and on the bottom. Sometimes certain offensive gases escape. The turbidity is caused by myriads of microbes which are living on the organic matter contained in the water.

All waters used for domestic purposes are more or less liable to pollution by microbes which may be injurious to persons whose temporary or chronic condition of health may not be good. It is, therefore, the first duty of the engineer who is to select a source and design works for supplying a community, to consider only those waters which are naturally healthful at the source, or those which can be artificially made so at a reasonable expense. While, however, artificial purification may accomplish all that seems to be required, yet, when there is a choice, preference should always be given to water from the purer source.

We shall now refer to the different known methods of artificially purifying waters in a sanitary sense.

Water may be thoroughly purified, or, we should rather say, sterilized, by the process of *boiling*, which, if continued long enough, will destroy all living organisms contained in

it. This safeguard is the one usually resorted to in the household when the city water is suspected. The length of time necessary for boiling has been very differently stated by different authorities. Professor Tyndall found that there are certain stages in the life of bacteria when they can resist the action of boiling water, but these stages are of short duration, and, according to his statement, if boiling is continued for several hours, it will permanently destroy every vestige of life. Other authorities give twenty minutes as a sufficiently long time to render the water harmless.

Another method of artificial purification is the *aëration* of water. It has been the common belief that water, when it is deprived of air, deteriorates and becomes unfit for use, but the waters of deep springs, which have a high degree of purity, sometimes contain no air. Water exposed to air dissolves some of its constituents, viz: oxygen, nitrogen and carbonic acid. When the water contains organic matter, a change takes place, and the absorbed oxygen causes an oxidation of the organic into mineral matter. This oxidation, however, is almost entirely effected by the activity of living bacteria. The carbon and nitrogen of the organic matter combine with the oxygen. It has been thought that mechanical aëration would hasten the process of oxidation, but as this can be accomplished only by increasing the number of bacteria, or by providing more favorable conditions for their activity, the belief in purification by artificial aëration has begun to vanish.

Experiments that have been made on this subject have directly shown that oxidation of organic matter in water, is not hastened by vigorously agitating it with air, even when air is introduced into it under pressure.* But the aëration of water may still serve a useful purpose. It will prevent stagnation by supplying the usual amount of oxygen, and, for the same reason, will prevent the growth of algæ therein. It will also remove disagreeable gases which may arise from stagnant waters, and finally it serves a useful purpose in certain waters containing iron in solu-

*"The Effect of the Aëration of Natural Waters." By Thomas M. Drown, M.D., Chemist of the Massachusetts State Board of Health.

tion, by oxidizing the iron and thus rendering the water more palatable.

Dr. Frankland, in London, has lately shown that a partial purification of water may be obtained by *agitation* with certain materials in a fine state of division, and allowing a subsequent sedimentation.* His experiments with coke and charcoal were especially effective. Water, agitated with one-fiftieth of its weight of finely-powdered coke, was found, after settling, absolutely sterile, that is, without a single organism.

A method of purification which may be discussed under this same head has lately been brought into prominence by Mr. Anderson, who has patented a process for agitating water with small particles of iron in a revolving cylinder. He had before noticed the purifying effect of passing water through spongy iron, but, as this soon became useless by the clogging of its pores, he conceived the idea of having small bits of wrought or cast iron dropped through the water, instead of causing the water to pass through the pores of the iron. This is done by a simple mechanical operation in a revolving cylinder. Through the agency of carbonic acid contained in the water the iron is converted into ferrous carbonate, which is partly dissolved and partly suspended in the water, and gives it a slightly greenish hue. When acted on the air contained in the water, the iron is converted into ferric oxide, which first coagulates the organic matter held in suspension, and then acts as a precipitant in carrying down with it, as it settles, the fine particles held in suspension. The water is subsequently filtered in order to remove the sediment caused by the iron and its included impurities.

An examination of water so treated shows that no iron has been left in it, and that the precipitate has freed the water from a very large proportion of the bacteria originally contained in it. The high degree of purity, however, which is claimed as a result of this process of agitating the water with iron, is due largely to the subsequent sand filtration.

*"Water Purification: its Biological and Chemical Basis." By Percy F. Frankland, Ph.D., etc., a paper read before the Institution of Civil Engineers.

Dr. Frankland has more recently made experiments to ascertain the value of *sedimentation* alone, without any addition of coke, charcoal or iron. He found in a number of cases that raw river water running into a reservoir in London contained from five to ten times as many bacteria per cubic centimeter as the water running out of the same.* It may, therefore, be of great economical importance that sedimentation should be allowed to take place before resorting to more expensive methods of purification, for the former process may reduce the extent to which the latter need be carried.

Another method of purifying water is the direct *precipitation* of the objectionable matter by the addition of chemicals, generally in solution. These form, with portions of the organic matter, insoluble compounds, which, in gradually descending to the bottom, carry with them the suspended matter, be it organic or mineral.† The result, therefore, is a clarification, and, to some degree, also, a purification, of the water.

The chemicals which are added to water for the purpose of precipitation, are generally lime, salts of alumina, or salts of iron. They cause a coagulation of the organic matter, forming flocculent masses throughout the water.

While the precipitation processes serve at times an excellent purpose, we should not forget that the resulting water, though clear, may not be pure. It is true that a very large number of bacteria is carried down with the descending flocculent matter. Experiments have shown that 98 per cent. of the original number may thus be removed. It is seldom, however, that more than one-half of the entire organic matter is precipitated from the water, and more than three-quarters of the number of bacteria, and thus the water may again become objectionable through the develop-

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* "The Purification of Water by Precipitation and Sedimentation." A letter written by Dr. Percy Frankland, F.R.S., to "Industries and Iron," December 8, 1893.

† They also carry down a large percentage of the bacteria. If, however, the water is allowed to stand long, the organisms first carried down will rise again and be distributed through the water.

ment of fresh bacterial life in the organic matter which is not removed.*

Lime is extensively used for precipitation, particularly when water is very foul. It readily coagulates organic matter, and, in quantities merely sufficient to effect a clarification, does not injure the water, because all of the lime generally sinks to the bottom. It is rarely necessary to use more than a half a grain to the gallon of water.

The action of alum is similar, so far as the method of purification is concerned, but it has the additional advantage of combining with coloring matter, and thus causing the water to become clearer than when lime alone is used. When water contains carbonate of lime in solution, the addition of alum causes the formation of sulphate of lime, carbonic acid and hydrate of alumina. The sulphate and the carbonic acid remain dissolved in the water, while the alumina forms a gelatinous or flocculent mass, which, as it settles down, drags with it the suspended matter which causes the turbidity. The alumina also forms insoluble combinations with some of the dissolved organic matter, and this is also precipitated. The amount of alum necessary to give perfectly clear water ranges from one-half grain to five grains per gallon. Too much alum will make the water acid and thus cause it to rust all iron with which it comes in contact. When a smaller quantity will not properly precipitate all the suspended matter, it is of advantage to add a small amount of lime sufficient to neutralize the acid developed by the alum.

The Chinese and other Asiatic people have long been familiar with this effect. They put a piece of alum into a hole in the end of a bamboo stick. The water is first stirred with this stick and is then allowed to settle.

Salts of iron are likewise excellent precipitants and, for some waters, are preferred to alum and lime. Ferric oxide is especially efficacious when in a nascent state, as already

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* "Report of Experiments upon the Chemical Precipitation of Sewage," made at the Lawrence Experiment Station during 1889. By Allen Hazen, Chemist in charge at the Station. Massachusetts State Board of Health. 1890. Vol. II. Pp. 737–91.

mentioned when speaking of the process of purifying water by means of small particles of iron. The coagulated ferric hydrate, in settling through the water, removes most of the bacteria contained therein.

Ferric sulphate and per-chloride are also used to coagulate the organic matter, but they are more expensive, and their action upon drinking waters, is less favorable than that of the substances already mentioned.

It has already been mentioned, under the head of sedimentation, that charcoal and coke, when finely divided, carry down much of the suspended matter. Finely divided clay, when in suspension, as in our western rivers, will act in a similar way, and thus, if their turbid water is allowed to rest, will carry down the major portion of the impurities.

Before we leave the subject of precipitation, we must mention a process which quite recently has been much discussed, viz.. the purification of water by electrolysis. Electricity is employed to produce a decomposition of the salts contained in solution and to transform into harmless compounds the organic matter contained in the water. When an electric current is passed through water containing chlorides, for instance common salt, these are gradually converted into hypo-chlorites, which destroy organic matter brought in contact with them. We are all familiar with the action of hypo-chlorite of lime, which is very commonly used as a disinfectant. By adding salt to water, or by using sea water, a hypo-chlorite of soda is formed which precipitates the organic matter and promptly destroys it by oxidation.

How far this process may be made available for the purification of drinking water is yet a question. At the present time, so far as I know, it is used only for the purpose of purifying a stream containing the sewage of Brewster, in the water-shed supplying the city of New York with its drinking water, and there only upon a small scale.

[*To be concluded.*]

NOTES AND COMMENTS.

ANNUAL REVIEW OF SCIENCE AND INDUSTRY.*

The production of crude iron is properly regarded as a fairly accurate barometer of the state of general trade and commerce. The figures of the year's production, accordingly, which have just been issued on the authority of the American Iron and Steel Association, reflect the pronounced depression in business which characterized the greater part of that disastrous period, viz.: the total production of pig iron in 1894 was 6,657,388 gross tons, against 7,124,502 tons in 1893; 9,157,000 tons in 1892; 8,279,870 tons in 1891; and 9,202,703 tons in 1890. The production in 1893 was 2,032,498 tons, or over 22 per cent., less than in 1892; and the production in 1894 was 467,114 tons, or over 6½ per cent., less than in 1893. The production in the first half of 1894 was 2,717,983 tons, and in the last half of 1894 it was 3,939,405 tons. The total production of pig iron in 1894 was the lowest yearly production since 1888.

The number of furnaces which were in blast on June 30, 1893, immediately after the panic of that year, was 226; by December 31, 1893, the number in blast had fallen to 137; on June 30, 1894, there were only 108 in blast; on December 31, 1894, the number in blast had increased to 185.

A glance at the transportation interests will show that the falling off of traffic during the year 1894, has had no parallel in the experience of the present generation. The enormous losses of income thus entailed have not only told severely against a large number of unfortunately situated or over-capitalized railway companies, forcing many of them into bankruptcy—but have also operated in placing a decided check upon railway extensions in almost every section of the country; and indirectly, by reason of the severe economies which these losses have enforced upon all alike, they have checked the demand for railway materials and supplies to an extent which even the most pronounced pessimist would scarcely have believed possible at the close of 1893. Rail-makers, locomotive-, car- and bridge-builders, accordingly have suffered alike, as the following brief statistical statements will demonstrate:

Some weeks must elapse before the complete record of new railroad construction will be available, so that we must be satisfied at this time with estimates, which may be accepted as approaching closely to accuracy. I present, accordingly, on the authority of the *Railway Age*, the following figures of the probable mileage of new railroad constructed last year. For the United States the new construction is estimated to have been 1,919 miles, and the significant comment is made that these figures are the lowest of any for the last twenty years. In the last five years the new mileage was respect-

*An abstract from the report of the Secretary to the stated meeting of the Institute, held January 16, 1895.

ively: In 1890, 5,670 miles; in 1891, 4,282 miles; in 1892, 4,178 miles; in 1893, 2,635 miles; in 1894, 1,919 miles.

* * * * The diminished figures of steel rail production have their explanation in the condition of things here exhibited. * * * * In locomotive building the same story is repeated. The *Railroad Gazette* estimates that the decrease in the number of locomotives built was nearly two-thirds as compared with the previous year. Reports from thirteen companies, which built 2,011 locomotives in 1893, give their output in 1894 as 695. The exhibit made by the car- and bridge-builders is even worse, but I will not weary you with the details. It is gratifying, in passing from these disheartening proofs of extreme industrial depression, to note the very general belief that the worst effects of this depression have been felt, and that the present year will witness the slow but steady return of the country to prosperous conditions.

* * * * An engineering work, which was begun in 1892, and which promises to have important results for the city of Chicago, was considerably advanced towards completion during the past year. I refer to the great Chicago Canal, which, when finished, will establish communication between the waters of the Great Lakes and the Gulf of Mexico. The general character of this undertaking is given in the following extract from the *Scientific American*:

"The headwaters of the Des Plaines River lie in Wisconsin, near Lake Michigan. The river runs to the south approximately parallel with the western shore of the lake, and, after it has reached the parallel of Chicago, trends to the southwest, and, passing through Joliet, joins its waters with those of the Kankakee River, forming the Illinois River. The combined waters run through the channel of the Illinois River to the Mississippi, emptying into it a short distance above the mouth of the Missouri River. Through the city of Chicago winds the small stream called the Chicago River, a devious creek with several branches. This enters into the lake. A distance of a little over ten miles intervenes between the lake shore and the Des Plaines River at Chicago, while between the Chicago River and Des Plaines River but two miles intervenes. At present much of the sewage of Chicago runs into the lake, threatening with contamination the water supply of the city, notwithstanding the fact that the intake of the water works is situated some miles out in the lake. Largely to avoid this contamination, the great drainage works have been undertaken. * * * *

"At Chicago there is a true divide, the waters on the east pouring into Lake Michigan, and on the west reaching the Gulf of Mexico, through the channels of the Des Plaines, Illinois and Mississippi Rivers. Should the divide be pierced, the waters of Lake Michigan would run into the Gulf of Mexico as well as into the Gulf of St. Lawrence, and an internal waterway, from the British Provinces through the St. Lawrence and the Great Lakes to the Gulf of Mexico, would be created. At present work is being done on this connection, and if all goes well, by 1896, the city of Chicago will have internal water communication with the Gulf of Mexico—which she will be able to utilize for the transportation of freight, as well as for the disposal of her sewage."

The estimated cost of this work is about $22,000,000, and it is being carried on (principally) by the State of Illinois, with partial aid of the Government. The date set for the probable completion of the canal is November 1, 1896.

The much-mooted suggestions for enlarging and improving the canal routes connecting New York with Philadelphia and Chesapeake Bay, are gradually assuming definite shape, and there is now a reasonable prospect that this work may soon be accomplished. These improvements are much needed, and the expense incurred will doubtless be justified by the consequent increase of commerce. I quote substantially from the *Scientific American* the following information bearing on the subject:

"The city of Philadelphia some months ago appropriated $10,000 to be expended in making preliminary surveys and maps preparatory to enlarging the Delaware and Raritan Canal, and this has been followed by the appropriation of a like amount by the city of New York, for the same purpose. In addition to this a bill is now before Congress, having already passed the House of Representatives, providing for the appropriation of a sufficient sum of money to commence the actual work. Plans are also under discussion to enlarge and extend the Dismal Swamp Canal and the Albemarle and Chesapeake Canal.

"The latest report of the surveyors of the Delaware and Raritan Canal stated that the full length of the proposed new route would be thirty-two miles. The surface elevation along this route is higher than in the case of the old canal, but it will probably be selected because it saves the building of two expensive overhead bridges. The new canal will then start from Raritan Bay, cross the Raritan River about eight miles below New Brunswick and enter the Delaware River at Bordentown. Eleven miles of its length will be an enlargement of the old canal. The other twenty-one miles will be an original excavation. It will have a depth of 24 feet, a bottom width of 90 feet and a surface width of 160 feet. It will be provided with two opening locks 500 by 60 feet, and four lift locks with a total lift of 50 feet. The entire cost has been estimated at $12,500,000. Of this amount $50,000 will be expended in deepening the channel of the Delaware River between Philadelphia and Bordentown.

"It is, furthermore, proposed to make connections with the Dismal Swamp Canal, and to widen and deepen this canal in a similar way. The Dismal Swamp Canal commences at Deep Creek, Norfolk, Va., and extends in a southerly direction to South Mills, N. C., near the head waters of the Pasquotank River, which empties into Albemarle Sound. The canal proper is 22 miles long and 60 feet wide, and is provided with five locks. It has an average depth of 8 feet. It extends from deep water to deep water. An enlargement is being planned. It is proposed to give it an average depth of 10 feet and provide two locks, one at either end, to be 250 feet long and 40 feet wide. The estimated expense of these improvements will be $5,000,000.

"The Albemarle and Chesapeake Canal connects the waters of the southern branch of the Elizabeth River, which has its mouth at Norfolk, with the North Landing River and North River. The canal is 14 miles long

and has an average depth of 8 feet. The present owners propose to enlarge this to about the size of the others, so that large ships may pass through the entire system."

The approaching completion of the Canadian Sault Ste Marie Canal is an event worthy of notice, from the fact, as the *Iron Age* points out, that it will constitute practically the last link in a chain of waterways on Canadian territory that has cost the debt-burdened Dominion over $67,000,000, and which, at no distant day, will allow ocean vessels passage to the northern lakes. There are still to be completed some unimportant links on the lower St. Lawrence, which, however, will entail no serious additional outlay. When it is considered that, of the present enormous traffic of the old Sault Canal (on the American side), and which, in 1893, amounted to 10,796,000 tons of freight carried in 12,800 vessels, and valued at $146,500,000, only five per cent. was in Canadian vessels, the conclusion is obvious that the object of these vast expenditures is to make the Dominion of Canada independent of the United States in the possession of its own highway to and from the northern lakes and the ocean.

Incidentally, it may be of interest to call attention to the fact that the traffic of the present American canal for the past few years has exceeded that of the Suez Canal. In 1893, for example, the tonnage passing the latter was 7,650,000, or 3,000,000 tons less than that passing through the former.

The contracts for a notable engineering work were given out at the close of the year by the New York and Long Island Bridge Company. The company proposes to erect a bridge across the East River from Sixty-fourth Street, New York, by way of Blackwell's Island, to Long Island. The structure, as planned, will be a four-track railway bridge, having two main channel spans of 846 feet each, with a span over the island of 613 feet, and cantilever arms at the ends of 192 feet, which would make the total length of the bridge proper 2,689 feet. The New York approach will be about 2,000 feet long, and the Long Island approach about 5,000 feet. Including the approaches, therefore, the structure will have a total length of 9,690 feet. About 50,000 tons of steel will be required in the superstructure.

The bridging of the Hudson River, at New York, has been seriously proposed, and the Government engineers have sanctioned two propositions, one for a cantilever structure with two river piers, and the other for a suspension bridge. Both of these contemplate a structure having clear headway of 150 feet, so as to constitute no impediment to free navigation. The estimated cost of these enormous bridges is $23,000,000 and $35,000,000, respectively. The consensus of engineering opinion respecting the relative merits of these plans favors the cantilever structure.

The necessary preliminary concessions have been granted for the construction of a railroad bridge over the Delaware River from a point below Bridesburg on the Pennsylvania side, to Fisher's Point, on the Jersey shore. The bridge is to be constructed by the Pennsylvania Railroad. The plan approved by the Government engineers and the City Councils is as follows: The approach of the Pennsylvania side will begin at Frankford Junction, on the New York Division of the Pennsylvania Railroad, and will connect

with the Camden and Amboy Railroad at Fish House Station, on the New Jersey side. The bridge will be 1,950 feet in length, and will have a double-track line of railroad, to be built at a clear height of fifty feet above high water. The width will be thirty-four feet over all. It will be constructed of steel and will be supported by six piers of masonry, rising fifty feet above the water. The bridge will have three fixed spans, 540 feet in length, and a draw span of 330 feet over all, providing for two clear openings of 125 feet each in the river channel. The piers under the fixed spans will be built of granite, sixty-seven feet long and twenty-one feet wide, standing forty-five feet in height above high water. The approach of the bridge on the Pennsylvania side of the river will be two miles in length, and on the New Jersey side one-half mile in length.

The Philadelphia Trades League, it may be noted, has filed a protest with the Secretary of War against the construction of the bridge on this general plan, on the ground that a structure with so small an elevation as fifty feet would form a serious obstacle to the navigation of the river, and would greatly diminish the value and check the future development of the nearly five and a half miles of river front within the city limits above the site of the proposed bridge. To avoid this serious objection, the Trades League asks that the height of the bridge be made seventy feet instead of fifty feet.

A commission has been appointed by the French Government to examine and report upon the feasibility of a scheme for a ship canal to unite the waters of the Atlantic with those of the Mediterranean Sea. The route of the proposed canal would cut across the neck of land joining the great Spanish Peninsula with the mainland; the termini of the line would be, respectively, Bordeaux on the Atlantic and Narbonne on the Mediterranean. This canal, if of sufficient size to accommodate ocean-journeying steam vessels, would cut off about two-thirds of the distance from the English Channel to Suez, as compared with the present sea route skirting the Bay of Biscay and the coast of Spain, since vessels from the North Atlantic to the Mediterranean and *vice versa* would be able to make the short cut through the canal instead of going around the coast of Spain. It is interesting to note that this is the third time that this project has been made the subject of investigation by the French Government, the persistance of its advocates being due most probably to the belief that the canal would afford the advantage of giving the vessels of the French Navy a passage either into the Atlantic or the Mediterranean without running the gauntlet of Gibraltar. Two commissions have already reported the project to be impracticable, on the ground of excessive cost of execution.

* * * In the field of electrical engineering, by far the most interesting enterprise is that of the Niagara Falls Power Company, with the general character of which you are all familiar. The problems to be solved in connection with the electric transmission have involved the most exhaustive and painstaking studies of theoretical questions connected with the design and construction of generators to insure the selection of the type and system of transmission which will realize the highest practical efficiency. In the determination of these questions the opinions of men of the highest scien-

tific repute were sought and obtained, and the result of these very thorough preliminary inquiries will shortly be apparent.

The great power-house is now complete, the turbines and vertical shafts up to the floor of the power-house have long been in place, and the three great dynamos of 5,000 horse-power each, built by the Westinghouse Company, from the designs of Prof. George Forbes, are finished and ready to be finally put in place.

It is stated that the first plant to be supplied with current from the Niagara installation will be the aluminum manufactory of the Pittsburgh Reduction Company—the owners of the Hall patents for the electrolytic production of the metal from a bath of fused fluorides, in which the oxide of aluminum is dissolved. For the purpose of this manufacture, the 2,000 volts two-phase alternating current generated by the Power Company's dynamos, requires to be converted into a continuous current of 160 volts, which is accomplished by transformers applied in a novel manner. The company will begin operations with an available supply of 2,000 horse-power, and should then be able to supply the numerous and growing demands of the industries for aluminum at prices low enough to admit of its use on a far more extensive scale than has hitherto been permissible.

The Carborundum Company, also, has made arrangements for using 1,000 horse-power. This company, it will be remembered, manufactures a compound of carbon and silicon by the electric furnace method, and the product, though the fruit of a comparatively recent discovery, has already assumed an important place in the arts, as an abrasive material.

Other enterprises of similar character, although of less magnitude, are under way. Of these, a notable one is the electric power transmission plant at the falls of the Willamette River, near Portland, Ore., where a great long-distance transmission is being installed. This plant, when completed, will employ twenty electric generators, each of 600 horse-power, and capable, therefore, of delivering the total amount of nearly 12,000 horse-power to Portland, eleven miles distant. A similar project for supplying 4,000 horse-power to the city of Sacramento, Cal., from a water-power situated about twenty-five miles distant, is approaching completion. The preliminary steps are being taken for the construction of an electric power transmission plant to utilize the water-power of the Susquehanna River. The plan is fathered by a corporation called the Susquehanna River Electric Company, and contemplates the damming of the Susquehanna River near Conowingo, Md., and the erection of a large electric power-house, similar to the one at Niagara Falls. The power obtained in this way will be supplied to Philadelphia, Wilmington and Baltimore, and other intermediate points. It is expected that it will be used extensively in operating street railways and electric lights. The land at the proposed site of the dam has been purchased, the surveys have already been made, and the plans have been made for an immense plant. It is announced that this work will be started in the spring of the present year. Other projects of like character are being industriously mooted in the electrical journals, and it will need only the encouragement of success in the several undertakings now approaching completion

to bring a number of others to the fore. It remains only to be added that the advances that have been achieved within the past few years in the solution of questions of dynamo construction, have radically changed the aspect of the problem of electric power transmission, and it is now reasonably safe to predict that we are on the eve of a departure from the existing order of things which may profoundly affect our present social and industrial conditions.

The past year witnessed a remarkable extension of the overhead trolley system, not only for city and suburban service, but also on long-distance lines. The most noteworthy of those extensions probably was made in our own city, where the completion and starting in operation of a great network of surface electric railways has taken place. A similar transformation has been made in the street railway systems of Baltimore and New Orleans, and the projects for long-distance electric railways that are under consideration, or in course of completion, are too numerous to mention. Thus, for instance, only a few links are missing in a continuous chain of trolley lines between Philadelphia and New York; while trolley service between Philadelphia and Harrisburg, Baltimore and Washington, Chicago and Milwaukee, will doubtless be established during the present year.

While on this subject, the experimental work undertaken in New York by the Metropolitan Street Railway Company in the development of a satisfactory underground electric conduit system adapted for city service, is worthy of mention; also, the fact that an extensive underground electric system is about to be constructed in Washington. In Chicago, work is well under way on a complete elevated electric railway system.

Of special interest, also, is the fact that a number of the steam railways are seriously considering the electric equipment of short branch lines, which, in several cases, has either been done, or is being undertaken. The much-talked-of project of a high-speed elevated electric railway between Chicago and St. Louis, it is understood, has been definitely abandoned.

It would be interesting to have, at this time, the statistics of the electric railway mileage of the United States, to exhibit the remarkable progress that is being made in this branch of our transportation system, but the data are not as yet accessible.

In relation to the storage battery, though no radical improvement in construction has appeared, the experience gained in connection with its auxiliary employment at central stations, has demonstrated that there may be opened for it in this direction a wide field of usefulness. The prolonged and almost continual litigation over the question of patent rights has, up to the present, greatly interfered with the proper development of the storage battery in this country. Within the past few weeks, however, the official announcement has appeared that one of the prominent companies has acquired a practical ownership of the fundamental storage battery patents. As the transfer of these patent rights to a single ownership will put an end to the deplorable legal complications which heretofore have deterred the public from taking any interest in the application of the storage battery, there is at length a prospect that the free development of the industry will be unhindered, and that

we may soon learn what are the real capabilities of this interesting type of apparatus.

During the past year a successful trial on the Erie Canal of the method of electric traction for canal towage attracted considerable attention, and led many to believe that steps would be taken promptly to test the efficiency of the system on a more extended scale. Thus far, however, nothing of importance has developed in connection therewith on this side of the water, although it may be of interest to notice the fact that a successful trial of the De-Bovet system of electric traction for canal boats recently took place on the St. Denis Canal, in France. A series electric motor actuated the towing pulley, a fourteen millimeter chain, placed at the bottom of the canal, being carried over the pulley to the extent of three-quarters of a turn, although half a turn suffices. A two-wire circuit running along the bank of the canal was connected to a 110-volt generator driven by a locomotive engine. The current was collected by means of two trolleys running along the wires and connected to the motor by a flexible cable, which was passed over a pulley at the top of the mast of the boat. The trial was completely successful, and showed that for an expenditure of 2,000 watts it was possible to make a 300-ton barge move at the rate of 2·8 kilometers per hour. The getting under way took place without shock, and the normal speed was rapidly reached.

The decision of Judge Carpenter, of the United States Circuit Court, in the suit instituted by the Attorney-General of the Uuited States against the Bell Telephone Company, praying for the repeal of the letters-patent No. 463,569, issued November 7, 1891, to Emil Berliner, and assigned to the company above named, has brought to a termination a case of unusual importance, not only in reference to its bearing on the telephone business, but also because of its disclosure of methods and usages in vogue in the United States Patent Office, which call peremptorily for substantial reform.

The decision of the Court was favorable to the contention of the plaintiff, and the Berliner patent was accordingly decreed to be void, and was ordered to be delivered up to be cancelled. The effect of the decision—if it should be sustained on an appeal, which will doubtless be taken—will be to throw open to the public all the essential elements of the art of telephoning. The present status of the art, in view of this decision, is concisely summarized in a recent editorial abstract which appears in the *Electrical World*, from which I quote the following paragraph :

" By reference to the detailed examination of the situation, it will be seen that at present all forms of telephone receivers and transmitters are free, and on January 15th the valuable patent on the use of the induction coil with the transmitter will expire. As a consequence, private lines may be installed and operated under the most advantageous circumstances. The situation as to large exchange stations, however, is still much involved, and, owing to the multiplicity of patents concerned and the scant knowledge on the subject of the requirements of exchanges outside of the Bell companies, it will be some time before it can be cleared up. It now seems that there would be much difficulty in economically operating any exchange of considerable size with-

out the aid of switchboard and other devices covered by Bell patents. When, however, the difficulties to be overcome are clearly defined and understood, the matter will come within the province of the inventor, and the conditions would have to be singular indeed if some method of meeting them could not be eventually devised. But if this should be done, it does not follow that competition with the present local telephone companies would be a simple matter. Their prior occupation of the field, the sagacious preparations, extending over a course of years, that were made with a view to prospective competition, united with a highly trained and efficient force, and exchanges in which the subject of economy of operation has been most exhaustively considered—all of this renders successful competition a question that cannot be taken for granted."

This litigation brought out most conspicuously one fact which, though familiar enough to those who are versed in the patent law and the modes of procedure that obtain in the Patent Office, the layman will learn with amazement. The record of this now famous case exhibits that the application for the patent was filed June 4, 1877, and that the patent was not issued until November 17, 1891, or more than fourteen years after the date of filing. It is thus shown to be possible, by the dexterous use of legal procedures which the usages of the Patent Office permit, for an attorney to delay almost indefinitely final action upon, and the issue of, a patent, whenever the interests of his client will be served by such delay. As I have already intimated, this is no news to the fraternity of patent attorneys, any one of whom will be able to state from the experience of his own practice that the record of this case, far from being in this respect exceptional, could be duplicated. Without venturing upon a consideration of the expediency of investing the Commissioner of Patents with judicial powers capable of such extraordinory exercise, I believe I affirm the opinion of every intelligent and unprejudiced layman in saying that the state of affairs which this case has disclosed constitutes an intolerable abuse which was never contemplated by the framers of the patent laws, and which calls for prompt and radical correction. The decision of Judge Carpenter fortunately paves the way for this much-needed reform, inasmuch as one of the grounds on which he decreed the Berliner patent to be void was the unwarrantable and unlawful delay in the issue of the patent which was intentionally acquiesced in by the Bell Company, and which thus constituted a fraud practiced upon the public.

In the field of electro-chemistry, there has been an unusual amount of activity, and the application of electrolytic methods in the service of the chemical and metallurgical industries has made substantial progress. During the past year an enormous electric refining plant was erected at the works of the Anaconda Copper Mining Company, in Montana, for refining the entire output of those mines. The electrolytic production, by various processes, of caustic soda and bleach from salt; the purification of sewage by electrolytic means; the electric tanning of leather; the electrolytic production of chlorate of potassium from the chloride; of white lead, by decomposing alkaline salts with lead electrodes in the presence of carbonic anhydride; these and numerous other problems in industrial chemistry have been attacked with considerable success.

The brilliant work of Moissan with the electric furnace has shown the feasibility of producing with this agency most of the rarer metals with comparative ease, in considerable quantities, and in a state of purity. The abrasive material called carborundum—one of the latest and most interesting products of the electric furnace—has already acquired an important rank in the industries and is now manufactured in large quantities. The interesting discovery of a cheap method of manufacturing acetylene in quantity by exposing an intimate mixture of lime and carbon to the intense heat of the electric arc in a furnace of this type, has been brought to your notice so recently that extended reference to the very important industrial bearing of the discovery will be unnecessary. * * *

The great problem of converting the potential energy of coal directly into electrical energy, without the wasteful intervention of the steam engine, has received the thoughtful attention of many investigators, and though its satisfactory solution has not yet been found, so much light has been thrown upon the subject that, at the present time, we know much more about the conditions that govern success or failure, than a few years ago. The first serious effort towards the solution of the question was made about ten or twelve years ago by Mr. Edison with his thermo-electric generator, in which he sought to attain the desired end by apparatus of highly ingenious construction, in which the operative feature was the magnetization and demagnetization of iron by rapid alternations of temperature. By the well-known law of induction, these alternations of magnetic intensity were utilized to generate induced currents in surrounding coils. This idea, promising as it appeared when first announced, its originator does not appear to have made any further attempt to develop in practice. What the estimated efficiency of this machine was, I do not at present recall, but it is tolerably safe to infer that it was considerably below that realized from coal through the agency of the steam engine, otherwise something more would have been heard of the invention.

The improvement of the older and better known thermo-electric generators, in which a series of compound bars or plates formed of dissimilar metals, and heated at their points of union, is caused to generate a current, appears also to have been abandoned as a practicable means of solving the problem.

In view of the fact, therefore, that the problem seems to be hopeless of solution from the physical side, it is particularly interesting to note that within the past year the opinion has gained ground that we may reasonably hope to solve it from the chemical side. The correlation between chemical and electrical energy is a well-established fact of science, and, in the case of many substances—carbon among them—is capable of being expressed quantitatively and with as great accuracy as the relation between heat and mechanical force, which finds its mathematical expression in the figures representing the mechanical equivalent of heat. In the voltaic cell, as is well known, the electric energy developed is derived from the direct conversion of the energy of chemical combination, and the quantity of the one, which it is possible to realize from an electrolytic cell formed of any pre-determined elements, may be calculated, in terms of the other, with the same accuracy as the possible

mechanical energy which can be developed from the combustion of a ton of coal. The solution of the problem of converting the potential chemical energy of coal directly into electrical energy, resolves itself, along this line of research, into the construction of voltaic cell in which the "cold" combustion of carbon shall be effected with an efficiency approximating nearly to that which theory demands.

Theoretically, this mode of solving the problem is attended with no difficulties; practically, it presents many, but not insuperable, difficulties. Indeed, although this field of investigation has only recently attracted serious attention, substantial progress has been made towards the actual accomplishment of the object in view. I will refer you, in substantiation of this statement, to the recently published experiments of Dr. W. Borchers, of Duisburg, Germany, who has devised a cell for the purpose in which twenty-seven per cent. of the energy of combustion of the fuel (in this case the combination of CO and O) is converted into available electrical energy. When it is considered that these experiments represent, practically, the first serious attempts at the solution of the problem by this method, these results must impress themselves upon thoughtful persons as very encouraging; especially significant do they appear, when it is remembered that the best results which it has been possible to realize by the indirect method of generating electric currents from coal by the intervention of the steam boiler and engine represent only about fifteen per cent. of the stored-up energy of the fuel.

In a paper before the German Electro-Chemical Society, Dr. Borchers described and illustrated two practical forms of electrolytic cells, one for using carbonic oxide gas, and the other for coal dust, and concluded by affirming his belief that "the problem of the cold combustion of the gaseous products of coal and oil, in a gas battery, and its direct conversion into electrical energy, can certainly be accomplished," a statement which, in view of what he has already demonstrated, appears to be quite reasonable.

In the field of industrial chemistry, I may supplement my comments on the progress made in solving numerous problems in commercial electrolysis, by reference to the interesting discovery of Messrs. Cross, Bevan & Beadle, of certain new reactions of cellulose (wood fibre), yielding derivatives which are found to be susceptible of many uses in the industries, and which give promise of even more extensive and valuable applications than that protean material, celluloid. The material is available in six different forms: the crude solution, dense cellulose in the mass, separate films and sheets, films and sheets on cloth backing, porous cellulose, and various admixtures of cellulose with foreign substances. The number and variety of uses suggested, and, in fact, partly realized for these products, are legion, and instead of enumerating them, I will refer you to the paper of Mr. A. D. Little on the subject, read before the Institute early last year and published in the *Journal*.

* * *

In the aluminum industry no pronounced advance may be reported. The electrolytic methods of production, represented by the Hall process in America, and the closely-related methods of Herault-Kiliani and Minet in Europe, still afford the cheapest means of producing the metal. The out-

look for any material cheapening of the cost of producing this metal is not very promising. The present electrolytic methods are susceptible of very little improvement, and the prospect for cheaper aluminum depends either on the discovery of some radically new mode of generating electric current, or of some very greatly improved method of producing the metal by chemical-metallurgical means. As the utilization of the energy of our great water powers promises to afford power at a cost of less than one-eighth of a cent per electric horse-power per hour, there would seem to be very little hope for reduction of cost in this direction. The probability that a chemical method will be discovered that will be capable of yielding the metal at lower cost than the present electrolytic process, it must be confessed, is extremely small. The possibility that such a discovery will ultimately be made, however, exists, and those who are best qualified to pass an opinion on this interesting subject incline strongly to the view that the cheapening of the cost of producing aluminum will be brought about by chemical methods which will enable us either to make the commercially pure metal directly from its ores by a furnace process, or which will enable the electric manufacturers to produce the pure metal from the crude ores without the expensive preliminary purification which is now a large item in the cost of manufacture.

Substantial advances have been made in connection with the production of alloys of aluminum, which are finding application in the manufacture of engineering, physical and draughting instruments, fine balances, domestic sanitary and plumbing appliances, etc.

The complete solution of the problem of soldering aluminum seems to be opposed by the serious obstacle of the high electro-positive nature of the metal. The method proposed by Mr. Joseph Richards, a member of this Institute, in which a small percentage of phosphorus is introduced into the solder employed, appears to have given more uniformly satisfactory results than any other that has thus far been proposed, though it must be said that it still leaves much to be desired.

The use of aluminum for kitchen utensils is steadily extending, and at present is the basis of a considerable industry. The suitability of the metal for vessels employed in the preparation of food has been made the subject of exhaustive investigation, and the consensus of opinion is now entirely favorable to it. From present indications, it appears highly probable that in the course of a few years the consumption of aluminum for kitchen ware will exceed the requirements of any other industry in which this metal is used.

A few years ago a favorite subject of discussion in the technical journals was the question of the permanency of the supply of natural gas. To-day the question is already practically answered by the actual exhaustion of the supply in parts of Pennsylvania and Ohio, and its rapid diminishment in others; while in Indiana the signs of impending exhaustion have already made themselves apparent in the great reduction of pressure. The fact is now fully demonstrated that the productive gas areas are limited in extent, and that the available supply is a rapidly diminishing quantity.

The recent revival of interest in the subject of aërial flight is a noteworthy circumstance, and within the past few years a really astonishing

amount of progress has been made toward the practical solution of this problem. The names which figure most prominently in this interesting field of research are those of Langley and Maxim. The recent experiments of the last named investigator upon a machine of large size attracted widespread attention. They appear to have fairly demonstrated the following facts: That a machine carrying its own engine, fuel and passengers, can be made powerful enough and light enough to lift itself in the air; that an aeroplane will lift a considerably greater load than a balloon of the same weight; and that it may be driven through the air at a very high velocity, and with an expenditure of power very much less than that required to drive a balloon at even a very moderate pace; and that a well-made and properly applied screw propeller obtains sufficient grip upon the air to propel a machine at almost any speed, and that the greater the speed the higher the efficiency of the screw.

Commenting on Mr. Maxim's results, London *Nature* believes that they "have certainly forwarded the problem of aërial navigation."

The remarkable experimental studies of Professor Dewar, of the Royal Institution of London, in connection with liquefied oxygen (which he has succeeded by highly refined and original methods, in producing, comparatively speaking, in large quantities), aside from their great scientific interest, have enabled him to demonstrate certain highly important facts that have direct practical bearing. He has been able to verify, for example, what had been before merely a scientific hypothesis, namely, that as metals decrease in temperature their conductivity for electricity increases, and his experiments give the strongest reasons for believing that when the temperature of absolute zero is reached, the metals reach the point of absolute conductivity. Furthermore, he has experimentally shown that the cohesive power of the metals is greatly increased by diminution of temperature.

The tensile strength of iron, for example, is shown to be increased at the temperature of liquid air from thirty-four tons per square inch (at the ordinary temperature) to sixty-four tons, and a like increase of cohesive quality is exhibited by every other metal. The magnetic property also is shown by his experiments to be increased at these low temperatures; an iron bar magnet, for example, showing an increase of fifty per cent. in magnetic strength.

On the other hand, non-metallic bodies are shown to behave in a manner exactly opposite to that of the metals, decreasing in conductivity as the temperature falls. To comprehend the extraordinary conditions of these experiments it must be remembered that the temperature of liquefied oxygen is 182° below zero of the centigrade scale, corresponding to 295° below zero F. At these temperatures, we have matter, as has been tersely stated, in *articulo mortis*. Chemical forces are in complete abeyance. Phosphorus, even, refuses to combine with oxygen, which has become as inert as nitrogen. A few degrees lower, and the last traces of that molecular motion we call heat would disappear, and matter, destitute of all active properties, would be dead.

An item of scientific interest which has given origin to extended discussion, was the announcement made, at the British Association meeting last

summer, by Lord Rayleigh and Prof. Ramsey, of a probable new constituent of the atmosphere. The alleged new element is described by these observers as being characterized by the same inertness as nitrogen, as somewhat heavier than nitrogen, and is believed by them to be present in the atmosphere to the amount of one per cent. by volume. They believe it to be either a new element, or a heretofore unknown allotropic form of nitrogen. The genuineness of this discovery has been called into question by several noted chemists, and especially by Profs. Dewar and Wanklyn. The scientific world must, accordingly, suspend judgment on the subject for the time.

Franklin Institute.

[*Proceedings of the annual meeting, held Wednesday, January 16, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 16, 1895.

Mr. H. R. HEYL, in the chair.

Present, forty-one members and four visitors.

Additions to membership since last report, six.

The tellers of the annual election held this day, between the hours of 4 and 8 P.M., made their report. The chairman thereupon announced the result of the election as follows:

For *President*	(to serve one year), . . .	JOSEPH M. WILSON.
" *Vice-President*	. . .	(no choice).
" *Secretary*	(to serve one year), . . .	WM. H. WAHL.
" *Treasurer*	(" " "), . . .	SAMUEL SARTAIN.
" *Auditor*	(" three years), . . .	FRANCIS LECLERE.

For *Managers* (to serve three years).

CHARLES H. CRAMP,	EDWARD LONGSTRETH,
GEORGE V. CRESSON,	SAMUEL P. SADTLER,
ALFRED C. HARRISON,	WM. H. THORNE,
EDWIN J. HOUSTON,	JOHN C. TRAUTWINE, JR.

For the *Committee on Science and the Arts* (to serve three years).

C. O. C. BILLBERG,	J. M. EMANUEL,	C. E. RONALDSON,
L. L. CHENEY,	J. LOGAN FITTS,	L. F. RONDINELLA,
JAMES CHRISTIE,	JOHN L. GILL, JR.,	SAMUEL SARTAIN,
D. E. CROSBY,	LEWIS M. HAUPT,	T. CARPENTER SMITH.
WM. MCDEVITT,	STACY REEVES.	

The chairman announced that a vacancy existed in the office of Vice-President, and one also in the Committee on Science and the Arts. It was voted to defer the election to fill these vacancies until the stated meeting of February.

The following nominations were received for Vice-President, viz. Col Chas. H. Banes, Mr. Henry R. Heyl and Mr. G. Morgan Eldridge.

The Secretary presented the annual reports of the Board of Managers, the several standing committees and sections, which were severally accepted.

A recommendation contained in the report of the Committee on Science and the Arts, that the Institute issue diplomas and certificates in certain cases in connection with its reports, was approved.

A vote of thanks was passed to the professors of the Institute and to the gentlemen who have given their services as lecturers. Also, it was voted that the thanks of the Institute be given to Mr. George V. Cresson, of the Board of Managers, for his generous co-operation with the Committee on Instruction in establishing a branch of the drawing school near Germantown Junction.

The meeting voted to defer action until next month on the proposed amendments to the by-laws affecting the organization and government of sections.

The Secretary presented a report of scientific and industrial progress for the year 1894, an abstract of which is published in the *Journal.* He exhibited also the following novelties: A specimen of calcium carbide, prepared by the electric furnace method, by —— Taber, a member of the Institute, and made the experiment of generating acetylene by dropping fragments of the substance into water: Two pieces of sheet aluminum, greatly corroded, which had formed the heel, or re-enforcing piece, of an extension shoe, and which had been worn for about one year. The maker of this shoe had hoped to find in aluminum a metal that would not be attacked by the secretions of the skin. The condition of the pieces showed that the metal was not suited for the purpose. (In view of this observation, some revision of currently accepted statements respecting the ability of aluminum to withstand corrosive influences of this nature, would appear to be necessary: An improved horse-shoe, devised by Mr. M. Hallahan, of New York. The invention is substantially a pad, made of vulcanized rubber, combined with canvas and backed with sole leather. It is a little more than the full size of the horse's foot across the heel, and forms part of the shoe. In applying the devices, the shoer fits the foot and pad with a three-quarter-inch steel shoe of uniform thickness. The space between the pad and the foot should be filled with tar and oakum.

Adjourned. WM. H. WAHL, *Secretary.*

BOOK NOTICES.

Electric Light Installations —By Sir David Salomons, Bart., M.A. Vol. II. Apparatus.

Sir David Salomon's book bearing this title has been known now for a number of years, and has run through several editions. His previous editions, although, from the title, having to do with installations in general, and hus purporting to be a book of large scope, have, nevertheless, been

confined entirely to the subject of electric lighting by means of accumulators. Vol. II, which now appears, does not seem to deviate from the line of its predecessor. This particular volume is entitled "Apparatus," and is largely descriptive of the specific types of machinery, accessories, etc., which are used in English practice.

While there are portions of the work which might be read with some degree of benefit, as, for instance, the chapters dealing with gas engines as applied to storage battery plants, we cannot but feel that the larger part of the work is of but slight importance. The study of electricity, both theoretical and applied, now comprehends so large a field, that at the best no one can hope to be more than vaguely familiar with the greater part of what is known. This being the case, it seems a pity that so many books should be published, bearing high-sounding titles, and sure to distract the attention of a large number of earnest workers, from books more helpful. The present work is one of a great many which have appeared during the last year or two, and which contain little else than recapitulation of the matter found in any good trade catalogue. To the live electrical engineer this book presents nothing that is new, and nothing that has not been said before, while the beginner would do better to devote his time in mastering the principles, than in expending his energy in reading catalogue descriptions. E. G. W.

Electric Lighting Plants: their Cost and Operation.—By W. J. Buckley. 8vo. Pp. 279. Illustrated. Chicago: Wm. Johnston Printing Company. 1894. Price, $2.

Despite the deprecatory terms in which the author, in the preface, informs his readers that he is "neither electrician, engineer, nor expert, but a salesman," the book he has prepared seems to us to answer the author's expressed purpose very satisfactorily, to wit: "to give intending purchasers of lighting plants such details as may aid them in forming a fair estimate of the cost of construction and operation of their proposed station."

His critical remarks on the various points worthy to be carefully observed by intending purchasers, are really worth attentive consideration, and should be worth to an intelligent reader in that situation many times the value of the book. The tables of costs, estimates, instructions to employés, etc., have practical value. Altogether, we have seen works more pretentiously introduced which were less worthy of perusal than this one. W.

Lettering of Working Drawings.—By J. C. L. Fish. New York: D. Van Nostrand Co. 1894. Obl. 8vo.

Many books have been written on the subject of letters and lettering, but we know of none more useful than this. The work will form a companion, in every sense of the word, to any draughtsman.

Simple rules are given for the construction of the letters, followed by thirteen plates giving specimens of lettering, which have been made up principally from working drawings.

Many of the letters shown are ornate, others are of the crazy order, but all are legible and easily executed with a pen or pencil.

We find trouble in reading the work at night, and hope the publishers will print future editions on paper which is not so highly calendered. R.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIX. MARCH, 1895. NO. 3

THE ANIMAL AS A PRIME MOVER.

By R. H. THURSTON.

[*Concluded from p. 121.*]

PART III. SPECIAL ENERGY-PRODUCTS: ELECTRICITY, LIGHT, ETC.; SUMMARY AND CONCLUSIONS.

Singular and unfamiliar energies are produced by the vital machine, either as incidental to the ultimate purposes of the apparatus, or as special final output for peculiar purposes. For example, it is known that electricity is produced in the muscular and nervous systems, in vertebrate animals, and that in some cases, as in that of the electric eel, in large quantities, and for peculiar and special purposes of offence and defence. The fire-fly, also, produces light for its own special purposes. It is supposed by some authorities that electricity is developed for the use of the internal telegraphic system of all animals and it is a "singular" product only in the sense

that we have not yet been able to make ourselves familiar with it and to determine just how it is employed and in what manner it is generated and transformed. In the case of the light-producer, the product is "singular" in the sense that it is not only unfamiliar as a system of energy production, distribution and transformation, but also as being rarely developed. We know only the glow-worm, the firefly and a few other organisms, such as the animalculæ of the tropical seas and certain bacteria, which are capable of transforming energy supplied them into light. In this case, it is also singular that the light produced should be almost, if not entirely, unmixed with heat, and, in this sense it is the most economical light production known. These two examples of singular product are so important and suggestive, as well as interesting from their mystery, that they demand careful consideration, particularly at the hands of the engineer.

Electricity has long been recognized as a vital energy, and the fame of Galvani, the distinguished professor of comparative anatomy at Bologna (1737–1798) was mainly established by his striking discovery (1786) of what is now familiar to biologist and physicist alike, as "animal electricity," or, as Daguin calls it, *l'électricité vitale*, the "vital fluid," according to the discoverer himself. The famous controversy which at once arose between Galvani and Volta, the contemporary professor of physics at Pavia, and which led to the publication of Volta's dictum: "When two heterogeneous substances are in juxtaposition, the one always assumes the positive the other the negative, electrical state," was a first step toward the determination of the fact that as externally produced currents will always affect the nerves and muscles, so internal currents may always be found, capable of affecting external substances. Nobili's discovery of the "proper current" directed from the foot toward the head of the frog (1827), as predicted by Humboldt just thirty years earlier; Matteucci's extended researches of later date, and the still more striking investigations of DuBois Reymond (1842), have proven both the existence of such currents in the animal machine and a drift, also, of electricity outward from

interior of muscle, or nerve, to the surface, which may probably be taken as a "leakage current," due, in part at least, to the fact that, even here, insulation is not perfect. The last-named investigator showed that the more powerful the muscle, in its natural condition, the stronger these electric currents; the heart, for example, exhibiting powerful currents and the muscular system of the intestines a comparatively weak flow. His well-known experiment, in which the galvanometer is made to reveal a current passing from an unflexed arm to the other side and into the arm, which, contracting its muscles strongly, grasps an object forcibly, especially interests the student of the vital machine as indicating, in correspondence with the fundamental laws of energetics in this case of electric action, as in thermodynamic operations, the reduction of the energy-supply by conversion into mechanical work.*

The experiments of the Italian physicists, and of Dr. Ure, on cadavers, are familiar proofs of the substitutive value of the electric fluid and the vital fluid, if, indeed, they are not evidence of their identity, and the still more familiar experiences of all who have had to work with electricity in any form at moderate or high tensions may be accepted as more convincing testimony of the relationship of the one form of energy to the other. The discovery by Pouillet, and the later investigations of Donné, Bequerel, and others relative to the now well-recognized form of vegetable electricity, constitute an interesting, if superfluous, confirmation of the idea that nature employs the electric current in her work much more generally than is popularly supposed.

The identity of animal electricity with the familiar forms of that energy is, perhaps, best shown by the fact that where, as in the gymnotus and torpedo—the best known among some fifty such creatures—the fluid is made the means of attack and defence, thus necessarily being given considerable volume and tension, it responds to every test customarily employed to identify and measure the voltaic current.

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*Recherches d'électricité animale. Annales de Chemie et de Physique, 3e serie, t. xxx, p. 119.

The assumption which, perhaps, may now be fairly taken as possessing a basis of probability, that electrical or some related or in many ways similar form of energy may prove to be an intermediary between the chemical energy known to be a necessary initial action in the reduction to the active form of potential energy supplied to the vital system, and those ultimate energy-products—mechanical power, heat, sometimes light, and always physiological manifestations—is strongly corroborated by the facts developed by research in those organisms which most extensively and strikingly exhibit that kinetic energy. It is known, not only that about fifty creatures are capable of applying the electric fluid to their own purposes, in defence and in pursuit of their prey, but that all species of the ray family have at least rudimentary electric organs, a fact first stated explicitly probably by Robin. Five species are known to be capable of producing a sensible, often powerful, electric discharge. Muschenbroeck, Walsh, Davy, Becquerel, Breschet, Linari, Matteucci, Moreau and others, some of whom have been elsewhere mentioned, have shown this fact and have revealed distinctly the identity of this energy of these fishes and other creatures, with the electricity now familiar to us in a thousand daily operations. Marey has shown that the discharge is effected by transmission of the mandate of the will to the storage battery of the animal at substantially the same rate that other nerve-actions are propagated.* He sums up his facts in a form which suits our present purpose well.†

He concludes:

(1) The rapidity of the nervous agent is identical in the torpedo and the frog affected by the electric discharge.

(2) "Lost time" exists and has the same measure in the electrical apparatus of the torpedo and in muscle, and the same is true of its endurance.

(3) The duration of the torpedo's discharge is about the same as the duration of the shock in the case of the electrified frog.

**Journal de l'anatomie et de la physiologie*, 1872.

†Animal Mechanism, p. 57.

(4) This period is about one-seventh of a second.

Davy produced all the phenomena of voltaic electricity from the vital organism; Linari and Matteucci similarly proved its identity, in action and effects, with static electricity and provoked the electric spark from the animal. If the idea of Fritsch is correct that the electrical generating and storage organs of the creature are derived from the skin, it would seem very probable, also, that the source of energy-transformation from potential to the kinetic, or from stored forms to motor forms, may be found in, or under, the cuticle. Bayliss, Bradford and others, however, attribute the currents observed in animals to the flow of fluids, perhaps to simple friction; while Biedermann thinks the katabolic action, breaking down tissue, is the source of the current passing inward; and the anabolic action, constructing tissue, is the cause of the reverse current. If the machine be, in any degree, electro-dynamic, this is a substitution of cause for effect.

Humboldt's account of the employment, by the Indians of Rastro de Abaso, of wild horses in capturing the gymnotus, at the sacrifice of an occasional horse by drowning, after being disabled by the shocks administered by the enraged gymnotus, and his statement, that he himself had received more powerful shocks than he had ever received from the largest Leyden jars, give some idea of the vigor as well as of the character of animal electricity. His experiments with Gay-Lussac, and those of Davy, Bequerel, Breschet and others, show it to be capable of performing every feat and exhibiting every phenomenon familiar to us as the result of voltaic action at high tension.

All research to date proves:

(1) That the electrical current in the animal system is produced for the purpose of effecting energy-transformations of, as yet, undetermined character and extent.

(2) That it is, in the electric fishes, at least, developed at will in quantity demanded for its intended work, as in other displays of energy, up to the limit of the nerve-power of the individual.

(3) That in all its characteristics it is similar to, if not

identical with, voltaic electricity, and thus unquestionably subject to all the laws of energetics, of electro-dynamics, of electrical physics, and of electro-chemical action.

The velocity of transmission of the nerve impulse is from 90 feet per second in cold-blooded, to 100 or 150 feet, in warm-blooded creatures—an exceedingly minute fraction of the speed of the electric current over good conductors. It thus requires about the tenth part of a second to telegraph from the brain to the extremities and obtain a response through the sensory nerves, or to produce reflex motions of muscles. DuBois Reymond found the electromotive force impelling the electric currents flowing in the nerves and muscles of the frog, to have the value of 0·22 to 0·25 volt in the nerve and 0·35 to 0·75 volt in the muscle.* Should it prove the fact that the active energy is electric and magnetic, the low voltage, if confirmed by measurement of the actually operating currents doing their regular and normal work, would indicate great strengths of currents at low tensions. The time required for action, at the nerve center itself, is something like 0·05 second.

Matteucci found that the passage of the electric current from the brain toward the extremities produced contractions of the muscles traversed; while the opposite direction of current caused annoyance, if not actual pain, and seemed only to affect the sensory nerves. He thought that this "polar condition" indicated that such excitation by something analogous to, if not identical with, the electric form of energy, constitutes the "nervous agency" of the system.

What is known to-day simply shows that electricity of low tension and comparatively large quantity, or some related form of energy, is, or may be, a product of transformations occurring in the body, having their source in the potential energy of the food supplied, and is the probable intermediary between the directing power of brain and spine and the elements of the voluntary and involuntary systems of muscles; that this energy is probably in constant circulation in continuously acting organs, and inter-

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* Encyclopædia Britannica, Art. Physiology, p. 26.

mittently, at least, in those actuated only by the will; and that the evidence of its presence may always be found in its leakage currents. It is certain that the production of electricity may be increased by the special development of its producing organs to such extent as to become a source of power and of safety to its user and of danger to enemies, exhibiting all the characteristic properties of the familiar forms of moderately high-tension currents.

Anatomists familiar with comparative biology know that the electric cells of the torpedo and its congeners are evolved from the underside of the skin, and by a process which seems simply that of muscle cell production with modification to its special purpose. This fact may be accepted as evidence, worthy of consideration at least, that the muscles contain within themselves the principle of animal power, and possibly, even, that this power is a modification of, if not identical with, the familiar forms of electricity. It is well known that muscular power may reside in the muscle, and that this local potentiality of energy display may be exerted by, and may even act rhythmically in, an organ, as the heart, detached from the body.

Light production by the vital machine illustrates another curious and impressively suggestive method of energy-transformation, the nature of which, and the essential prerequisites for which, are still among the mysteries of this ever-present sphinx.* The light radiated by the living machine has been studied by many investigators, and something has been learned of its production and its characteristics. It is known to be produced in a superficial, transparent tissue, blanketing the parts of the creature exhibiting luminosity, and containing a fat of peculiar structure and composition, which may be burned at extraordinarily low temperatures, giving out a light almost absolutely free from heat. It can thus be utilized in the animal system and, only light being produced, but a minute fraction of the energy demanded in the production of our more familiar

* "The Great Problems of Science," R. H. Thurston; *Forum*, September, 1892.

lights is required for this transformation. In its distribution, but *a fraction of 1 per cent.* of the energy thus expended takes the form of heat; while, in the common gas, or candle, or oil flame, ninety-nine per cent. of the energy is wasted in the form of heat—worse than wasted, since the heat thus produced is usually a source of discomfort as well as a material loss.

The vital machine, as a light producer, thus appears to have an efficiency of production approximating unity.* It has 400 times the light value of the gas flame, 40 times that of the electric incandescent lamp, and 20 times that of the best arc lamp. But the electric current utilized in these cases is derived from heat energy transformed by the heat-engine and the dynamo at, usually, the expense of four-fifths to nine-tenths its original potential amount; thus making the light of nature, as developed in the vital machine, from 200 to 4,000 times as efficient as the best and the worst, respectively, among our present artificial lights, if we assume no wastes in the production of the light-giving material. This would be the case if, for example, its wastes of energy, were there any to occur in the process, were to find use in further transformation, or application, in the economy of the system, as the heat of the exhaust steam of a steam engine in a woollen mill often has as great value for heating purposes as if taken direct from the boiler. Could this kind of light be obtained as the product of artificial methods of energy transformation, the result in economy of energy, of power and of fuel would be among the most tremendous of all the marvellous products of human invention.

Technically stated, the problem is: to produce ether vibrations having a frequency of 5×10^{14} per second, without admixture of other periodicities. Tesla attempts it by electrostatic action; nature does it perfectly by what seem to be chemical processes. How shall we ultimately accomplish this seductive task and emulate nature while comply-

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* Langley and Very, on the Heat and Light of the Fire-fly. Smithsonian Contributions, 1892.

ing with those economic laws which always control, and often seriously impede, the progress of the engineer?

Vital force and energy, the force and energy which constitute vitality, which are the characteristics of animal life, may easily be shown to be apart from that higher life of the soul and the intellect which constitutes the *ego*, which *is* the individual. They reside, not in the brain, or in its directing power, the mind, but pervade the animal frame, and are found active throughout the vital machine. Life, in this sense, is seen in the motions of the decapitated trunk of any animal, and the reptiles often live a long time with brain removed. All the functions of purely animal life continue, and the taking of food, its digestion, the act of respiration, that of blood circulation, and the whole "automatic" operation of the system, essential to continued vitality, goes on. This independence of the vitality of all mind is seen in the spermatozoa, which live independent lives for hours, and even in some animals, as in the bats, for months at a time. It is seen, very probably, in the white blood-corpuscles, which, as they float in the stream of vital fluid, change form, seize upon each other or upon the surfaces of their channels, and otherwise exhibit independent life. In fact, it may be fairly presumed that they are, themselves, the principle of life, its method of importation into the animal system. But this is not all. The vital principle attaches to every part, and the heart, removed from the body, continues, for a time, pulsing with its own independent life, the vital principle surviving long enough to produce many repetitions of the natural, rhythmic, automatic movements of the organ. In man—as intellection is entirely unessential to vitality, and, when unconscious, as when sleeping, when under the influence of anæsthetics, when suffering from concussion or other injury to the brain, the whole animal system continues in action with more or less accuracy, under the impulse and direction of the vital power—unconscious life continues, in some cases, weeks and months.

The probability that the vital functions are independent of the intellectual and moral life, and of brain action, is also

evidenced by the facts that the muscle, even when excised, quivers with vitality for a time; that it exudes carbonic acid when working, that it reduces lactic acid, decreases the amount of compounds present soluble in water, and increases the quantity of those soluble in alcohol; decreases glycogen, increases sugar; and all this when the flow of blood, with its burden of nutrients and of oxygen, is cut off from it. Blood entering the living and working tissues is always changed, in life, and issues with a new composition. The tissues are thus "laboratories, in which materials abstracted from the blood are transformed."

An excised intestine continues its peristaltic movements for an appreciable time. The heart of the rabbit beats sometimes a half hour after excision; the right auricle continues after the organ as a whole has become quiescent, and has been known to exhibit motion fifteen hours after death. The same independent and automatic action has been detected in the dog's heart four days after the death of the animal. The cold-blooded animals exhibit still more persistence of this local and independent life of the organ, and the heart of the frog has been known to pulsate with the motions of life, as a whole, for two or three days after removal from its nerve connections. Every organ is a motor; every protoplasmic cell is an elementary vital system.

The motor and other movements of the machine are absolutely independent of the peculiar nervous and mental characteristics of animal life. This is shown not only by the facts elsewhere mentioned in a similar connection, but also by the seemingly intelligent action of the sensitive plants and many other vegetable organisms, by the movement of the vegetable as well as of the animal protoplasms, by the energetic action of the white corpuscles of the blood and of the amœboid cells of both animal and vegetable protoplasms. Heat, light, electricity, chemical and mechanical stimuli, alike, all provoke displays of motor forces and energies in the simplest known forms of vegetable and animal structure, and absolutely independently of intelligence, will, nervous power, special circulatory and respiratory organs or, of

location in the organism of which they form the most elementary part. The rhythmic action of the human heart, the voluntary movement of the animal frame, the entrapping of its victims by the sensitive plant, the motions of the bacteria, the changes of the amœba and the protoplasmic cell, are, all alike, exemplifications of the inherent residence of motor-energy under conditions which involve entire absence of all the machinery of thermodynamic, or electrodynamic, motors of any sort as yet familiar to science.

It is thus evident that the vital energy is independent, on the one hand, of the familiar physical energies and forces, and, on the other, of the mental powers, of intellectual and soul life. It pervades the whole system, as do the physical energies, and may attain great development without reference to the condition of the physical or the psychical energies. The doctrine of Quesne, "psychism," is to this degree afforded some support. But the now universally accepted doctrine of the evolution of the world from an earlier chaos compels us, it would seem, to admit that all energies and forces, and all matter, aggregate out of space, and Quesne's proposition may be extended to every department of physics and psychics. All space is pervaded by heat, light, electricity and magnetism; why not with vital and spiritual energies?

The office of the vital force and its energy is apparently to give direction to the coarser physical energy of the muscle. It is the director of the telegraphic current which notifies the energy of the muscle when and how to exert itself. It co-ordinates the automatic movements, controls the system as a whole, as well as in detail, and is itself the principle of purely animal life. The organ which mainly controls and directs it, which is constructed to differentiate it from other energies, to give it form and purpose, to afford it a vehicle, is the spinal nerve of the vertebrate, and the equivalent organ in other creatures.

The psychical energies, including consciousness, intellection, emotion, which are essential characteristics of the vital machine, and which, in the case of those with which we are principally concerned, at least influence to an important

degree its power, endurance and efficiency, all depend, for their effective display and fruitful exertion, upon the preservation in good health and perfect form of the upper brain. A touch upon the surface of that organ impairs the action of the mind; the destruction of a ganglion takes away the power of expression if not of thought; the lesion or degeneration of its tissue measures a proportional loss of psychic energy. With the organ sound and strong, its action depends, as every day's experience shows us, upon its nutrition and repair. Like the body, it is seen to be a machine which guides and applies energies derived from external sources. All its energies come of an initial supply brought, through the blood channels, from the digested food; and both body and brain exhibit characteristic modes of guidance and application of the transferred and transformed energies originally stored in air and food. Body and brain are apparatus for absorption, transformation and employment of characteristic forms of energy. Their methods of absorption, modes of transformation, and processes of application constitute important and attractive, as well as legitimate, problems in physical research. Tracing back the path by which all matter came in from space to construct the material world, and retracing the path over which the energies came out of the ether, and its accompanying stock of all the energies, are companion problems.

The origin of energies displayed in the vital machine is found in the food consumed, and the apparatus of the body is simply, as is now well proven, employed in the freeing of these energies from their potential form in the chemical affinities of oxygen for carbon, hydrogen, nitrogen and the elements of various other compounds, and the diversion and direction of the resultant energies of various kinds and always equivalent quantity, in the performance of internal and external work. Brain, nerve, muscle, gland, all give proper direction to appropriate energies; none originates energy or has power, intrinsically, of doing work. They are all characteristically and kinematically similar to the organs of the machines constructed by man. But the ultimate physical source of all energies, so far as identified, is

the heat and light of the sun; while, in turn, the source of the energy of the sun's rays is presumed to be the mechanical energy of colliding atoms, molecules, star-dust, all celestial bodies, the comets, planets, suns, worlds. The distinctive energies are simply, as we suppose, different modes of motion of atoms and molecules and masses, if physical; but we find no light yet thrown upon the nature of the more subtle energies of vitality, of intellection, of mind, or upon their relation to matter.

Conclusions of serious import, of singular interest, of engrossing attractiveness, and of wonderful possible result, may be deduced from what has preceded; some of these conclusions are positive and certain, some extremely probable, others bare possibilities, so far as we can now trace them, and the possibilities are of such inconceivable magnitude and importance, should they be found to have a substantial basis, that, great as are the consequences of the positive deductions, the further investigation of the potentialities will undoubtedly be considered by men of science a matter of even superior importance. Some of these conclusions are:

(1) The vital machine is not a heat-engine, subject to the thermodynamic laws governing all known forms of thermodynamic machinery produced by man up to the present time.

We cannot assert that it is not a heat-engine in the sense of being a machine, which, by as yet undiscovered methods, directly transforms thermal into dynamical and other forms of energy; but it certainly cannot employ expansible fluids and transform energy by their expansion through a wide range of temperature, and it as certainly does greatly exceed all heat-engines in efficiency, both ideal and actual.

(2) The vital machine is an energy-transforming apparatus, in which the supplied energy is employed in useful transformations in far higher degree than in any energy-transforming machine or system yet produced by man to render available the potential energy of oxidizable substances.

(3) The vital machine must operate through methods of

energy-transformation yet unknown to science, though undoubtedly absolutely scientific and intelligible, once discovered.

The source of energy is perfectly well known, and the primary steps of the process determined, up to the completion of the preparation of the substance containing the potential energy furnished for transfer into the organs of the body, and for immediate transformation by chemical action. The resulting products are all probably identified and most of them well understood and quantitatively determinable; but the intermediate processes of transformation of potential into actual energy, and of transformation of one form of energy into another, as yet are veiled from our sight and concealed from our touch.

(4) These methods, whatever their character, produce mechanical energy more cheaply, as measured in energy consumed, than any known prime motor; develop heat at minimum cost in the same terms; in some cases produce electrical energy in considerable quantity and at high tension, by some probably direct transformation; occasionally produce light of almost absolute purity and perfection of economical character, and, in all intelligent creatures, supply the mind with an instrument utilizing physical energies for intellectual demonstrations.

(5) All these products being considered, this vital machine is enormously more efficient than any apparatus yet invented by the human mind, and illustrates methods of energy-transformation which, if they could be applied in industrial operations in place of the heat-engines, would afford inconceivable amelioration of the condition of the race, and to a less, but nevertheless considerable, degree, of his attendant creatures, both by giving the power of securing the utmost possible duty from our stores of latent available energy, and by prolonging the life of the race by indefinitely removing the period of exhaustion of those stores.

(6) The best evidence yet secured by research seems to indicate that the method of energy-transformation in the vital machine is one which directly transforms the potential energy of the food, as developed by chemical combinations,

into kinetic form, sometimes perhaps simply by chemico-dynamic change, sometimes by chemico-electric transformation; and this in turn, and possibly also the energy due to oxidation of food, and, to some extent, of the muscle itself, into mechanical power, into the vital energy of the automatic system, and into the form of energy producing brain-work.

(7) The vital machine may produce electricity as one principal output of its working processes, and probably by some direct system, without intervention of either heat-energy or dynamical power.

(8) The vital machine may produce light-energy in substantially unadulterated form, and by some process which does not involve either high temperature or the production of heat, or other energies, to be rejected as waste.

(9) It seems most probable, in view of what has been here collated, that the vital machine is some form of chemico- and electro-dynamic engine.

We know that the vital machine is not thermo-dynamic in the sense of being a heat-engine of any known class. We find in electricity the apparently next most available form of energy for use in transformation into dynamic and thermal and other forms, and many accept this as a provisional, a working, hypothesis. This was long ago hinted at by the greatest scientific men, the greatest minds, it would perhaps be fair to say, that have illuminated the history of the race. A century ago, Benjamin Thompson, (Count Rumford) a keen "Yankee," with uncontrollable inclinations toward scientific research, showed, to his own satisfaction, and to the extent of proving to others its probability, that the animal system constitutes a machine of higher efficiency than any steam engine.* Joule, as long ago as 1846, working with Captain Scoresby, concluded that the animal motor "more closely resembles an electro-magnetic engine than a heat-engine," and this is reaffirmed by Tait in our own day.† Sir William Thomson, now Lord Kelvin,

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* "Rumford's Essays," 1800.

† "Tait's History of Thermo-dynamics."

in his papers of about 1850, adopts the idea of Joule, and introduces the principle of Carnot, and says explicitly: "When an animal works against a resisting force, there is not a conversion of heat into mechanical effect, but the full thermal equivalent of the chemical forces is never produced; in other words, the animal body does not act as a thermo-dynamic engine, and very probably the chemical forces produce the external mechanical effects through electrical means." We have now seen how all investigations made before and since that date, so far as interpretable, point to the same conclusion:* that the machine is not a heat-engine.

The possibilities of improvement by simulating or parallelling nature are seemingly stupendous. Could the chemical energy of fuel oxidation be directly transformed into dynamic energy; could it even be changed by double or by indirect transformation, as through the intermediary of electricity, and in such manner as to insure a full equivalence of utilizable energy, it is evident that we might anticipate a conversion as economical as we now attain in the transformation of mechanical into electrical energy, and, consequently, many times as large a return for outgo as we at present realize, and correspondingly lengthened time of exhaustion of our stores of primary energy. At first thought, the possibility of an economic gain in power-production, by following nature in energy-transformations through processes which involve the organization of a sugar manufactory as a source of fuel supply, may seem somewhat unpromising; but, when it is considered that sugars and glycogens are but carbon and water, and that the chemist has successfully attacked many other more unpromising cases, as the synthesis of madder, and of the various other commercial substitutes for natural products, the possibilities, even seen from a financial standpoint, are not apparently absolutely to be ignored. Similarly, could chemical energy be directly and fully transformed into light, where needed, and as effectively as nature performs these

* "Mathematical Papers," Vol. I, lviii, p. 505.

operations of energy-transformation in the vital apparatus, the enormous expenditure, the fearful wastes, now going on, even in our production of out-of-door light by the use of the electric arc, would be reduced to a fraction of their present amounts, and to an insignificant fraction of total costs. Could vital energy be identified and brought under control, or could that mysterious energy which is its servant in directing and producing animal power, be securely gained and its processes understood and controlled, it would seem possible that direct transformations of energy—which probably means by influencing molecular and atomic rather than molar motion—might be made possible to man, and all this impressive and wonderful chain of consequences caused to follow.

THE APPLICATION OF ELECTRICITY TO THE BLEACHING OF TEXTILE FIBRES.*

By LOUIS J. MATOS, Chemical Engineer.

The lecturer was introduced by Prof. Sadtler, of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Of all the operations through which the textile fibres are passed in the manufacture of fabrics, none is of greater importance, and it should be remarked with emphasis that none has received a greater share of attention at the hands of practical mill men, technologists and chemists, than that of *bleaching*.

Referring to my subject, I think it most fitting to make a few remarks of an historical character, which may serve as a preface to this most recent stage to which the art of bleaching has advanced.

The art of bleaching has been known and practiced from the earliest times. The products from the looms of the early Egyptians and Phœnicians were brilliant examples of the art, and bore silent testimony to the esteem with which

* A lecture delivered before the Franklin Institute, November 30, 1894.

the fabrics were held by the inhabitants of the other nations who traded with them.

At one time the Dutch appear to have controlled entirely the bleaching of linens, large quantities of which, in the raw state, were shipped from other countries to Holland, to be bleached, and were then returned.

As the trade increased, causing a greater demand for the bleached goods, the time could not be spared for exporting the woven material to be bleached and reshipped, and it became necessary to perform the bleaching at the home of the industry. As a consequence the Irish process was developed, and became a very important trade factor.

The earliest process of bleaching in Great Britain was conducted with great care and attention to details. Fields of immense area were devoted wholly to the practice of the art, which, in the early days of the eighteenth century, was carried on by whole families, and the secrets of the art were handed down for generations from father to son. The trade was an eminently respectable one, and the products of certain bleachers were highly prized.

The earliest method of bleaching, of which we have any positive knowledge, consisted merely in spreading the fabrics on the grass, and exposing them to the action of the direct sunlight and of the dew, for periods of time varying from days to months; and, notwithstanding the many advances made in the art, it is worthy of note that, up to within a very recent date, many of the finest bleached fabrics were treated in this way. It may be remarked that one brand of linens is to-day bleached by a process very closely allied to this primitive one, and which may be briefly outlined as follows: The fabric is treated to an alkaline solution prepared by leaching wood ashes, the action of which is to dissolve from the fibres, such natural, or intentionally added, oils or greases. The material is then well washed in running water in order to remove the last trace of alkalinity, after which the fabric is exposed in the fields for several weeks, The material is then gathered in, worked in a bath of sour milk, again well washed, and the exposure in the fields repeated. According to the kind and quality of the goods,

the entire process here described was repeated several times, or until the desired degree of whiteness was obtained.

As will readily be understood, there is nothing in this process which can, in the slightest degree, injure the fibres, and, as a consequence, many of the treasured linens of the olden time are still in an excellent condition of preservation.

To an eminent French chemist (Berthollet), we are indebted for the first use of chlorine, which reduced the time of exposure in the fields, from weeks and days, to a few hours, but it was long after his experiments that the new order of things became general; in fact, it did not become commercially possible until our common "chloride of lime," or "bleaching powder," became an article of trade. The old school bleachers, of course, fought hard against the new agent, but, like every new and substantial advance in the art, it entered the field to stay.

The advent of bleaching powder marks the commencement of modern bleaching, and I shall take a few moments of your time in reviewing the important methods as applied to the principal textile fibres.

Cotton is never bleached in the unmanufactured condition, but in the manufactured state is frequently subjected to the process. *As yarn*, it is first "boiled out" with very dilute caustic soda, to remove the oil or gum, then washed or not, as desired, then immersed for one or two hours in a clear bath of bleaching powder, then washed to remove excess of bleaching liquor, and finally passed through a very weak bath of sulphuric, or hydrochloric, acid. When in the condition of *warps* (which may be 1,200 yards in length), it is subjected to the same treatment, except that special machines are required for the handling of threads of such great length. In the form of *woven fabrics*, peculiar apparatus, and special care and skill are required, and great ingenuity is displayed in the mechanico-chemical part of the operation. Two systems are in use, which are known respectively as the high pressure and low pressure systems. The essential difference between these lies in the length of

time the goods are subjected to the boiling. In both, also, the operation is divided into two stages. The first, in which the cleaning of the goods is effected, consists in boiling with lime or soda, followed with a weak acid (termed a "sour"), then with soap and soda, followed by a wash. The second is the bleaching proper, in which the goods are brought, for a definite length of time, in contact with the actual bleaching agent, followed by a wash, and a passage through very dilute sulphuric acid, after which the goods are allowed to lie in heaps for a time, then well washed, and dried over revolving cans heated by steam.

Modifications of the above processes have appeared from time to time. A notable one was that of the Messrs. Mather & Thompson, and is admirably suited for warps and piece goods. The important feature in this process resides in the use of carbonic acid gas, by which hypochlorous acid is liberated, which, in turn, effects the whitening of the fabrics.

The previous remarks cover the essential points governing the bleaching of cotton, and I may state that the same principles, with only slight alterations, are applied to the bleaching of linen and jute.

Animal fibres are never bleached with any of the compounds of chlorine, for the important reason that all such compounds impart to wool a yellow color, instead of the white color desired. Wool and allied fibres, however, are beautifully bleached by means of sulphur employed in the form of sulphurous acid gas, the damp yarns or fabrics being suspended in a closed chamber in which stick sulphur or brimstone is burning. The process is too well known to require lengthy explanation. Animal fibres are also well bleached by means of a solution of some sulphite, preferably the sodium sulphite, which yields results equal to the "sulphur house" method.

We have now reached the point where brief reference should be made to the use of peroxides—notably, those of barium, hydrogen, and lastly, of sodium—in the technology of bleaching. Of late, these substances have found extensive application in the textile industry, and their consump-

tion, particularly that of the last two, is continually increasing.

Cotton bleaching with the peroxides has not yet reached commercial importance, but wool and silk are treated in great quantities, the course of the operations with both being substantially the same. Peroxide of hydrogen occurs in the trade as a liquid which reaches the bleacher's hands directly without further treatment than to dilute it largely with water, and to neutralize the bath with ammonia or other alkali, when the fabric or yarn is immersed until the desired degree of whiteness is obtained. Peroxide of sodium, on the other hand, is in the form of a coarse powder, which must first be dissolved in water, then decomposed with a definite quantity of sulphuric acid, the excess of which is neutralized with an alkali, after which the goods to be bleached are immersed. The chemical control of these two bleaches is the same, as hydrogen peroxide is also the agent liberated in the latter case, and suffers the same decomposition. The strength of the baths is determined by means of a solution of potassium permanganate.

BLEACHING WITH ELECTRICITY.

Of all the many and varied uses to which the electric current is put, there is none of more interest to the textile chemist than its application to bleaching. It should be explained at the outset that electricity *per se* is totally devoid of any bleaching properties, and that the textile chemist simply avails himself of the property of the electric current to effect certain chemical decompositions, which he is able to utilize advantageously in his art.

The earliest attempts to use electricity for this purpose are somewhat clouded in obscurity, but it is certain that the credit for the first commercially available results are due to Mr. Eugene Hermite, the inventor of the process I am about to describe in detail.

The bleaching liquor employed in this process is produced by the action of the electric current upon an aqueous solution of a metallic chloride. The one found to be most desirable, owing to its greater economical value, is that of magnesium,

although the chloride of calcium, or of aluminium, may be used with the same result. As will readily be understood, upon passing a current through such a liquid, there occurs a simultaneous decomposition of the chloride present and the water. The result of this electrolytic action is the simultaneous liberation, at the positive pole, of chlorine and oxygen. These two gases—in the nascent state—unite at the positive pole, with the production of an unstable compound possessing, to a very great degree, effective decolorizing properties. Simultaneously also, at the negative pole, the action of the current liberates magnesium, and as the magnesium instantly decomposes an equivalent of

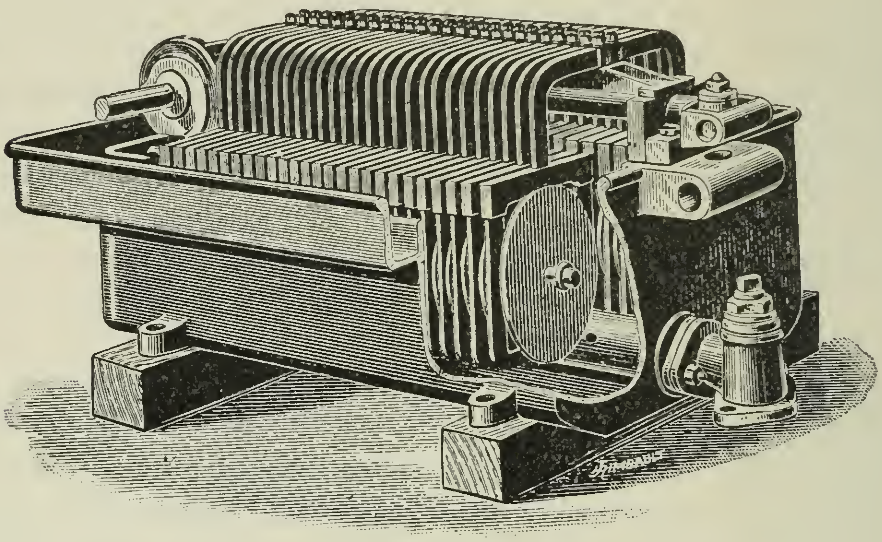

FIG. 1.

water, we obtain, as products of this reaction, hydrogen and oxide of magnesium.

Now, if we add to the electrolyzed solution, or bleach bath, some vegetable fibre—for example, digested and washed wood-pulp—the natural coloring matter of the fibre is destroyed by the highly oxidizing power of the chlorine-oxygen compound previously mentioned, and the chlorine, which is now set free, immediately unites with the hydrogen, forming hydrochloric acid, and this, in turn, in the presence of the magnesium oxide, dissolves that substance, re-forming the original salt in solution. After the pulp has become sufficiently bleached, the liquor is drained off, run back

into the decomposing or electrolyzing vat, and, after the addition of a small quantity of fresh magnesic chloride, it is ready for another operation, on passing the current. The pulp only requires to be washed, as is ordinarily done at the present time in the common bleaching powder process, and is then ready for conversion into paper.

Thus we see that but two elements are consumed in the operation—electricity, and the coloring matter of the substance to be bleached.

The electrolyzer, which is the most important piece of apparatus in the plant, is shown in *Fig. 1*. It consists of a vat, or tank, of galvanized iron, provided with a tube of zinc, perforated with holes in order to facilitate the circulation

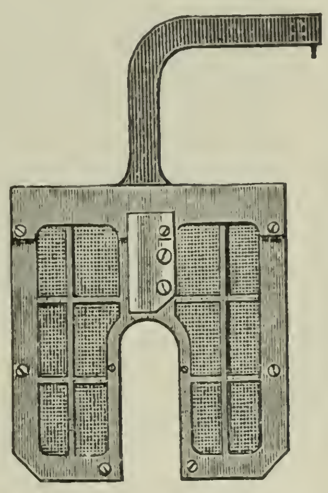

FIG. 2.

of the liquors. The negative electrodes are made of zinc in the shape of disks, and are secured to horizontal shafts, which, by proper gearing, are caused slowly to revolve. Between each pair of these disks are placed the positive electrodes, *Fig. 2*, each of which consists of an ebonite frame, holding, with the necessary firmness, a net, or perforated strip, of platinum. Each of these pieces of platinum is soldered by its upper edge to a piece of lead, and is completely isolated. Every frame of the positive poles communicates, by means of a piece of lead, to a bar of copper which traverses the electrolyzer.

The bar of copper to which the positive electrodes are attached, is in communication with the positive pole of the

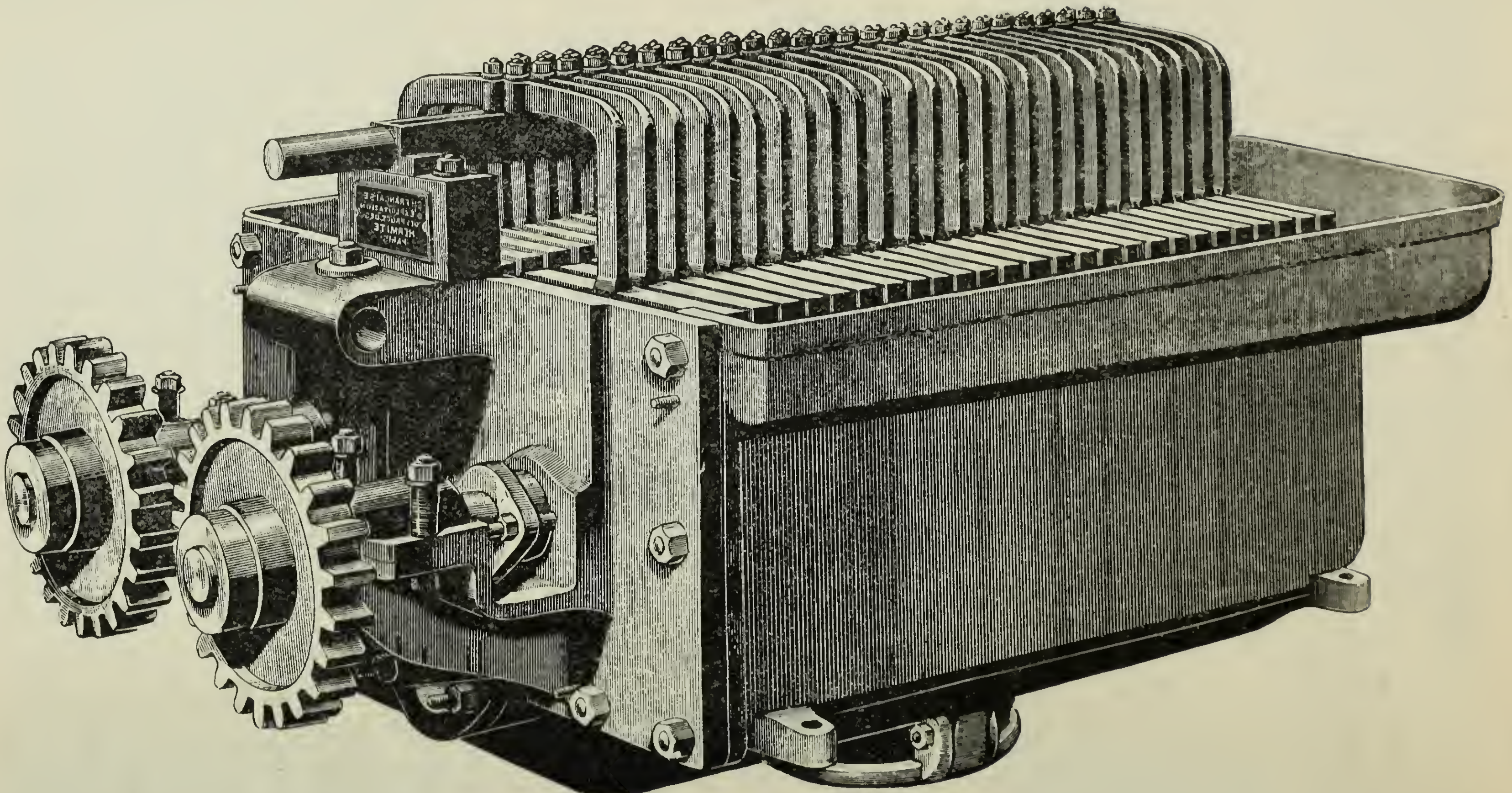

FIG. 3.

dynamo. The current is distributed through all the electrodes of platinum, and passes through the liquid to the disks of zinc forming the negative electrodes, which are connected by means of the tank, or vat, with the negative pole of the dynamo.

In order to maintain the negative electrodes at the proper distance apart, ebonite blades are fastened to the positive electrodes. At the lower portion of the box, or tank, is a gate, or door, which permits of access to the apparatus for cleaning; a valve is also provided for drawing off the liquor should this become necessary.

When several electrolyzers are employed in a battery, the negative pole of one is connected to the positive pole of the next in the series, and so on to the last one.

The current strength ordinarily employed in the electrolyzer is from 1 to 1·2 ampères, and with a corresponding electro-motive force of 5 volts. Instruments for measuring the strength of the current are placed in the circuit, and give at any moment a record of the force utilized.

The electrolyzers require no special attention; about once in every month the apparatus is thoroughly cleansed with water through the door previously mentioned, applied by means of a rubber hose; it is not necessary to dismantle it for the purpose. The wear of the electrodes, in consequence, is very slight.

The conductors, which join the electrolyzers and which bring the current from the dynamo, are made of bars of commercially-pure copper; the cross-sectional area of these bars varies with the distance between the dynamo and the electrolyzer.

It is always advisable to locate the dynamo and the electrolyzer as close to each other as possible.

Fig. 3 shows the large type of electrolyzer, with gearing in place to revolve the negative poles. *Fig. 4* shows a complete electrolyzing apparatus, embracing dynamo, electrolyzer and storage tanks, in position.

The Dynamo.—For this work a very strong type of machine is required, and it should be so constructed as to be capable of yielding its maximum duty—running day and night.

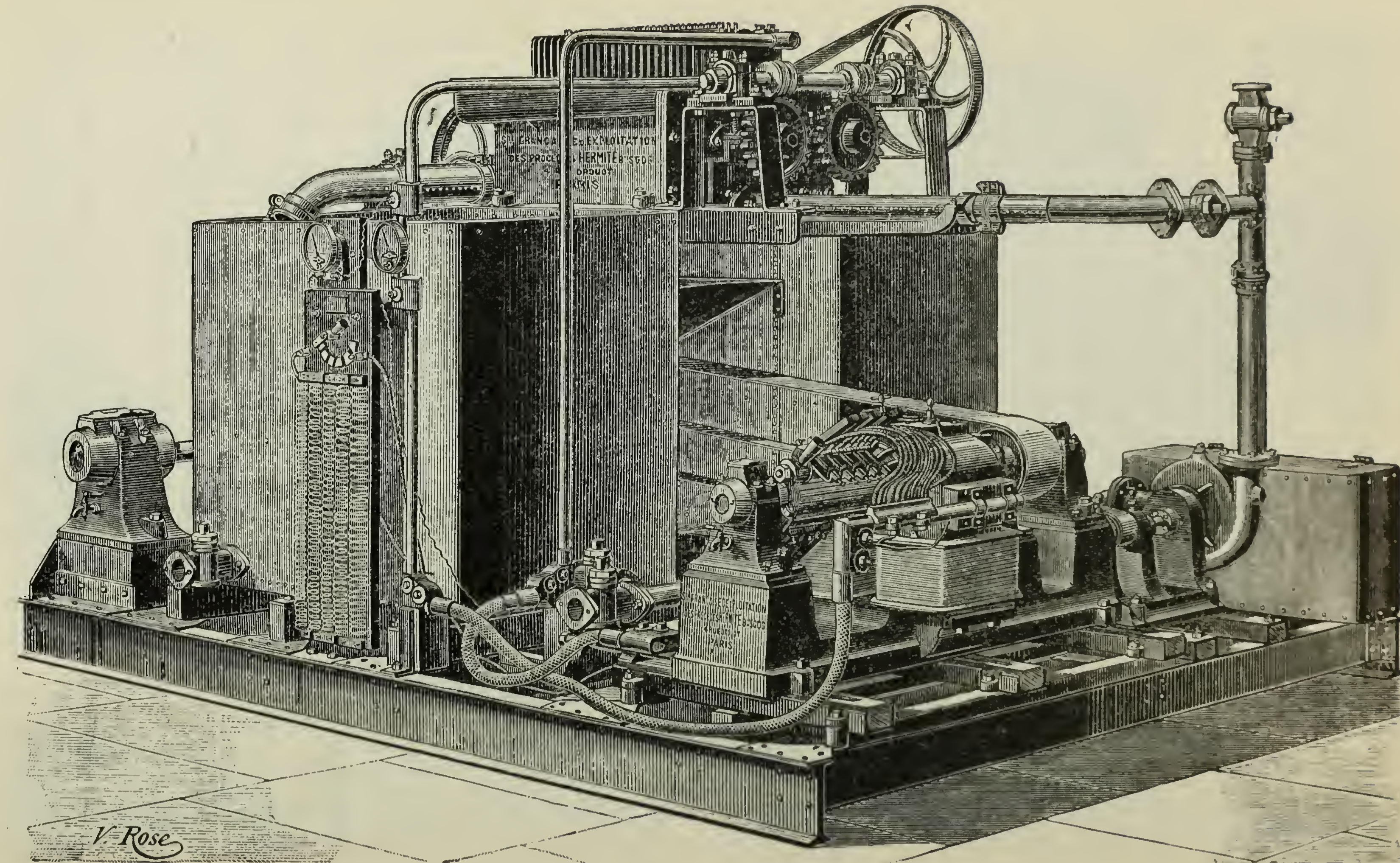

FIG. 4.

The Bleaching.—Bearing in mind the remark, previously made, respecting the peculiar action of chlorine upon animal fibres, it will be understood that the electrolytic process is inapplicable to them. We will confine our remarks, in consequence, to the bleaching of vegetable fibres, in connection with which much has already been accomplished with the process, and where there is still room for important improvements.

The fibre of most importance is, of course, cotton, and of this I shall speak first.

Cotton occurs in the form of a silky hair, which, when examined under the microscope, is revealed to us as a flattened tube, more or less twisted, and of a pearly-white color. It consists almost wholly of cellulose, with certain admixtures which are natural to it, such as moisture, several coloring matters—collectively termed "endochrome" oils—and a certain amount of inorganic salts. The quantities of these admixed substances peculiar to cotton are small, but, in the processes of converting the crude fibre into a manufactured product, certain other substances are added, such as oils, fats, starches, sizes, mineral matters, etc., all of which must be removed before the goods can be properly bleached. To do this it is necessary to subject the goods to a preliminary boiling or scouring.

Electrolytic Bleaching of Slubbing.—In this state, cotton is difficult to bleach, owing to the mechanical obstacles; nevertheless, it is done, and with remarkable success. Preliminary scouring is out of the question, and the electrolyzed solution is allowed to act directly on the material. The contained waxy matters, and those which are insoluble, are not acted upon by the solution, but the latter causes a decomposition of the coloring matter, which is converted into carbonic acid. The pectic acid is changed into a soluble pectate of magnesia, and the remaining mineral matters are dissolved. The greatest difficulty encountered is in causing the liquid to penetrate evenly into every part of the slubbing, but this is overcome by the use of pressure.

The length of time required for the immersion varies according to the color of the cotton treated, according to

the degree of white desired, and also according to the amount of chlorine and oxygen contained in the solution. Compared with the old method of immersion in the chloride of lime solution, the time can be very greatly prolonged without injury to the fibres. After bleaching, the cotton is removed, carefully washed with water slightly acidulated with sulphuric acid; this is followed with a rinse, the excess of water is removed, and the stuff is finally dried in the ordinary way.

Electrolytic Bleaching of Cotton on Cops and Bobbins.—Some difficulty is experienced in successfully bleaching yarn that is wound upon tubes or spools, owing to the resistance offered by the threads when superposed, but, by employing the conditions advised for the bleaching of slubbing, the difficulty is overcome. The cotton is acted upon by the bleach liquor of suitable strength, and, owing to the rapid action of the solution, the fibres are bleached during the ingress of the liquid.

Electrolytic Bleaching of Yarn and Cloth.—These offer the fewest obstacles. Yarn is bleached in a series of tanks supplied with the solution of constant strength from the electrolyzer. Cloth is similarly treated, except that it can be passed through the bath in a continuous form.

Electrolytic Bleaching of Linen and Hemp.—These fibres differ very much from cotton in the amount and nature of the extraneous matters which they contain. Linen is made from the fibrous part of the flax plant. The flax fibres are bound together by a cement-like substance, which must be removed in order to isolate the individual fibres. The removal of this substance constitutes the very important process of "retting," of which several methods are carried on. The oldest, and perhaps the best known, is the retting by fermentation, which is a kind of rotting of the ligneous matter. After this is removed, the subsequent operations of bleaching and dyeing are in order. It has been found that if these fibres are subjected to the action of the electric current in the bleach-tank, the oxygen, which is given up very readily, oxidizes the constituents of the vegetable cement, converting them into resinous

bodies, and thereupon at once proceeds to exercise its bleaching powers. When the fibres have assumed a yellowish or reddish color, the oxidation is finished, further treatment in the electrolytic bath is stopped, the material is removed and subjected to the action of boiling caustic or carbonated alkalies, either with or without pressure. This boiling operation effects the more or less complete removal of these resinous bodies, and leaves the fibres in a very clean and free condition, ready for further treatment. To bleach, all that is now necessary is to subject the fibres to a simple passage through the electrolytic solution, when a white of extreme brilliancy is obtained, and a silky feel is imparted to the fibres, which can be obtained by no other process, if the fibres have been retted in the ordinary manner.

Electrolytic Bleaching of Linen Threads.—Threads made of electrically retted fibres are of great purity, containing, besides cellulose, the natural coloring matter, and the residues of the vegetable cement, and, from what has preceded, it is easily seen that the bleaching of yarns is devoid of any difficulty. In comparison with the ordinary bleaching-powder process, that of Hermite has the decided advantage that the liberated gases, which do the bleaching, do not, as is the case in the old method, act injuriously upon the fibres. A modification of cellulose—termed "oxy-cellulose"—is formed in the old process, which is responsible for a considerable loss of fibre.

Electrolytic Bleaching of Jute.—This fibrous substance is one of a group closely allied to linen, but it has been quite impossible to bleach it on account of its feeble resistance to oxidizing agents. By way of comparison, I will describe the method most generally in use, at the present time, for bleaching this substance:

The goods are scoured in a bath containing half of one per cent. of silicate of soda, and kept at a fair heat; then washed and passed through a bath of sodium hypochlorite, containing about one per cent. of available chlorine; well washed, passed through a weak bath of hydrochloric acid; then washed again. The bleaching by the Hermite process,

which resembles that for linen, consists in the preliminary removal of the cutose and vasculose (vegetable cement) by conversion into resinous bodies, and the extraction of these by treatment with soda or other alkali. The actual bleaching is done by means of the electrolyzed solution, worked in a tank, in the same manner as with the ordinary chloride of lime process.

APPLICATION OF ELECTRICITY TO THE BLEACHING OF PAPER-PULP.

Having considered the several bleaching processes as applied to the textile fibres which are met with in the ordinary course of manufacturing operations, I will now bring to your attention another condition of fibrous materials, the isolation, bleaching and finishing of which, demands the highest qualities of both chemical and mechanical skill. I refer to the manufacture of paper.

The art of paper-making is very old, very interesting, and, when all the points are considered, it is seen to be a very elaborate process. It must not be thought for one moment that the elegant specimens of papers and cardboards, which almost daily come under our attention, are the results of any one series of experiments. As a matter of fact, such examples of skill are the final products of a process of evolution.

Many of you, no doubt, have been through a paper mill, and have seen the process of making great, long sheets, or rolls of paper, of exquisite whiteness and brilliancy, and have seen also the great bins of rags, collected here and there, from which the fine paper is made. For the information of those who have not seen the process, I will describe it somewhat briefly.

The rags are first assorted according to quality, the cleanest and finest pieces being set aside for the very finest linen papers. They are then cut into small pieces and boiled in a solution of lime, caustic soda, or a mixture of lime and soda-ash. This operation loosens the dirt, and prepares the material—called pulp—for the subsequent pro-

cesses. The next operation is the washing, which has for its object the removal of the soda or other alkali used. Then comes the bleaching, which is ordinarily done by a solution of chloride of lime, the strength employed being usually about half a pound of bleach to the gallon of water. The bleaching is done in vats, called "potchers." When the pulp has been sufficiently bleached, it is again washed and run into a machine known as a beater, which serves to reduce to a finer state of division the smaller particles of pulp, after which the material is pumped into the paper-making machine.

Wood, of the poplar, spruce, pine and other allied species, is largely employed in the making of paper, and, strange as it may seem to the uninitiated, products of excellent quality are made from wood, which compare very favorably with the best of those made from linen.

To render the wood fit for paper-making, it must be chopped into small pieces, and boiled with caustic soda in large vessels. This treatment reduces the wood to its elements; that is, it causes the solution of the resinous and other matters which hold the individual fibres together. After this treatment, the pulp is washed with water, and run through a machine, called a pulp-strainer, which removes any particles of woody matter that have escaped disintegration in the boiling. The clear pulp is now ready for bleaching, which is done in almost the same manner, and with the same materials, as with rags. After the bleaching, the pulp is washed and is now ready to be converted into paper.

Referring to the bleaching, paper-makers are confronted with several serious obstacles in the process as it is now carried on with the aid of chloride of lime. The chief of these are its cost, which every one wishes to reduce; the amount of room required; the unpleasantness of the operation; and, finally, the fact that, although fibre has been bleached to a beautiful white, it is lacking in strength. There is another objection, which, though a negative one, is important, namely, the fact that there are some woods, readily avaïlable and otherwise desirable for the paper-

maker's use, which cannot be worked because of the impossibility of bleaching them properly by this process.

Chemically, raw wood is closely allied to jute and linen, in having present in its tissues binding materials which hold the fibres together, and which impart a decided color to the wood. Boiling with caustic soda resolves these

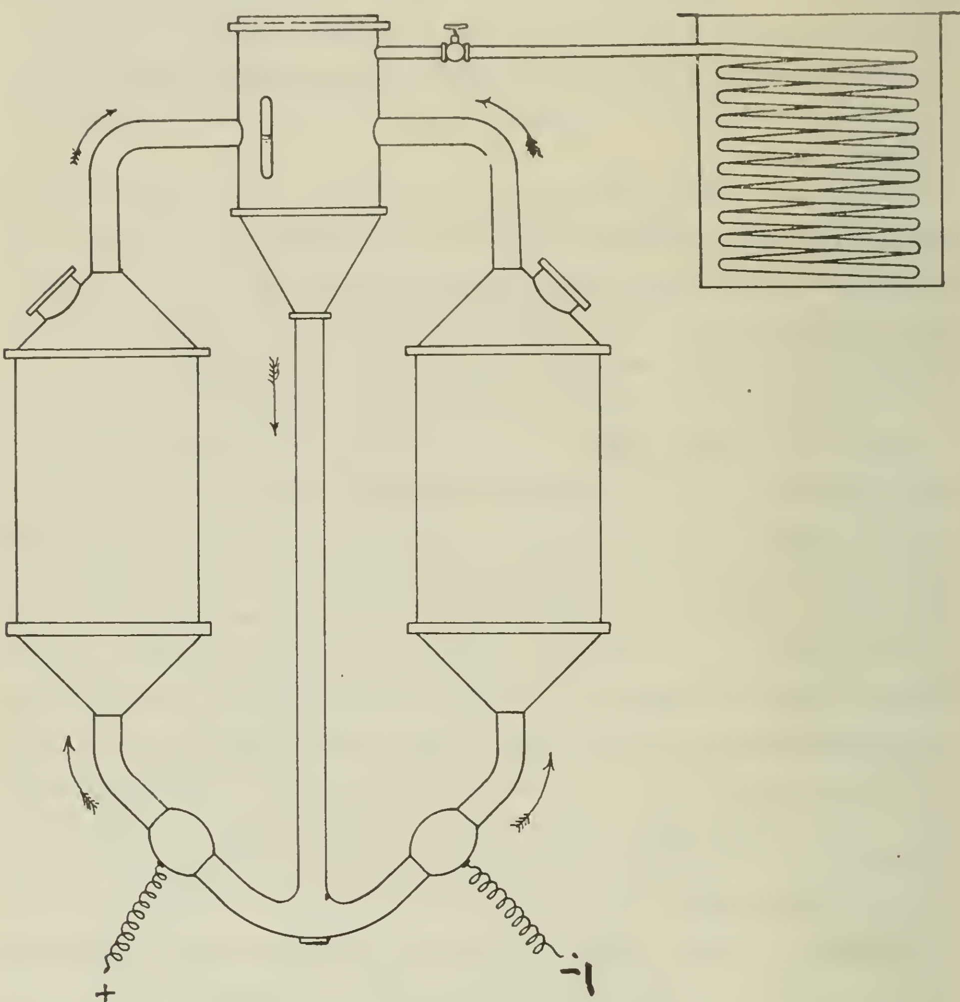

FIG. 5.

binding materials into soluble products which are easily removed by subsequent washing. Now, let us suppose that the boiled and washed wood-pulp is worked, or kept in agitation, in a solution from an electrolyzer. What should happen? Simply this: the remaining traces of the binding material should be completely decomposed, and the coloring matters pervading the wood cells completely oxidized

to carbonic acid, leaving the wood fibres in a condition to truthfully deserve the name "cellulose." This is what the electrolytic processes actually do for the paper-maker, and I shall take a few minutes to describe the methods proposed, and those in use, for making merchantable products.

The process of Karl Kellner, patented in 1885, consists mainly in subjecting the wood-pulp to the action of a solution of common salt at a temperature of 284° F., or thereabout, and with the simultaneous passage of the electric current. The strength of the salt solution is recommended to be about eight per cent., and the time of its action about

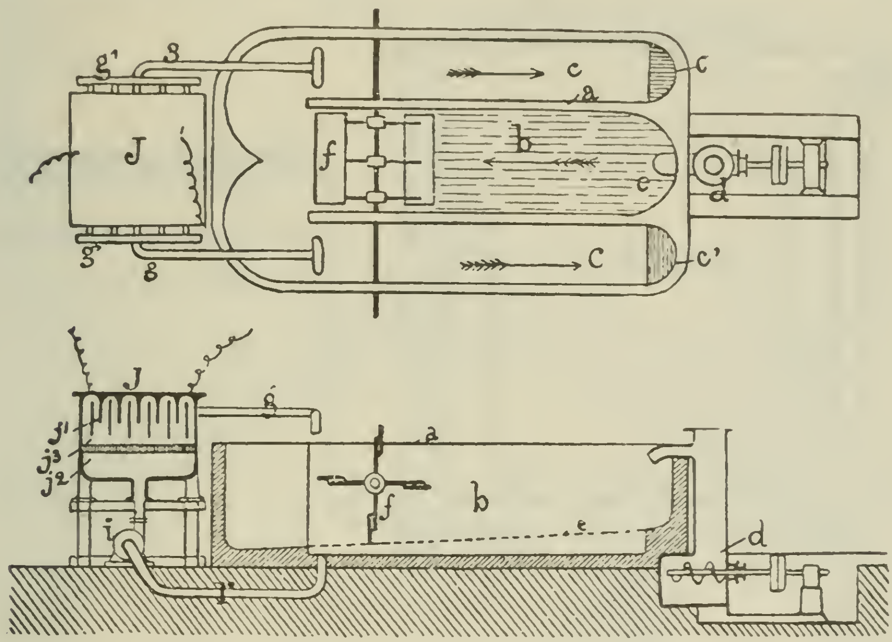

FIG. 6.

three to three and one-half hours. In the Kellner apparatus, the poles, which are of carbon, are placed in the lower part of the apparatus, *Fig. 5*, and connected with the dynamo. In operation, the course of the current is alternated at intervals of fifteen or thirty minutes. For a further bleaching of the pulp, an apparatus is used resembling very much a so-called "hollander," having two compartments suitably connected with pipes, as shown in *Fig. 6*. In this apparatus the bleaching solution contained in the electrolyzer is forced, by a rotary pump, through and around the positive and negative poles and out of the electrolyzer, into the compartments contain-

ing the pulp, which is kept in constant agitation by means of a revolving paddle wheel. The fresh and untreated pulp enters the apparatus at one end and leaves it through a different channel near the same end. The whole machine is provided with a screen which serves to keep the pulp separated from the partially spent, or exhausted, bleaching liquor. This spent liquor is pumped back through the electrolyzer, where it is again rendered active, and the operation is thus made continuous.

Another form of apparatus, embodying in its construc-

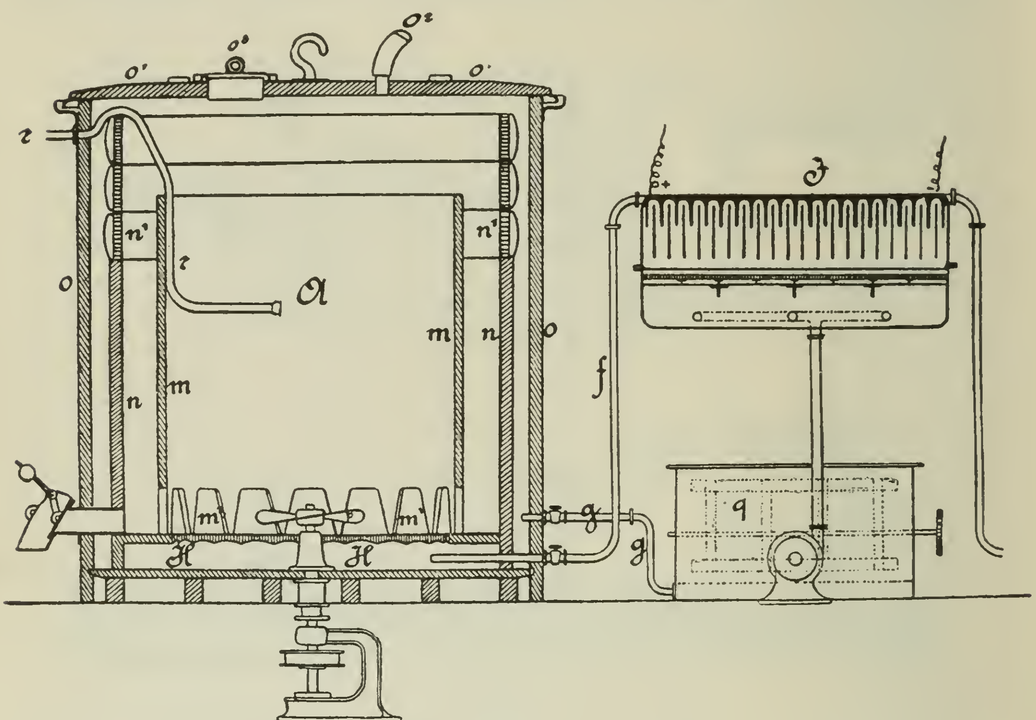

FIG. 7.

tion the essential principles of the machine just described, is shown in *Fig. 7*. Here are three tubs, or vats, one within the other, and in the center of the bottom is placed a propeller, or mixer, intended to thoroughly agitate the contents. Connected with these vats, and conveniently placed, is an electrolyzer, fitted with a pump, by which it is caused to deliver a volume of freshly electrolyzed liquor, and, at the same time, to receive an equivalent volume of spent, or partially exhausted, solution. Here is shown the arrangement constructed for continuous working, and where the

highest chemical and mechanical economies appear to be completely realized.

Naturally, the main issue involved in the whole subject of the technical application of electricity to textile bleaching, resolves itself into the question: Can a process which involves the use of such seemingly elaborate apparatus compete successfully on the commercial scale with the chloride of lime process? and I answer, yes. I am prepared to

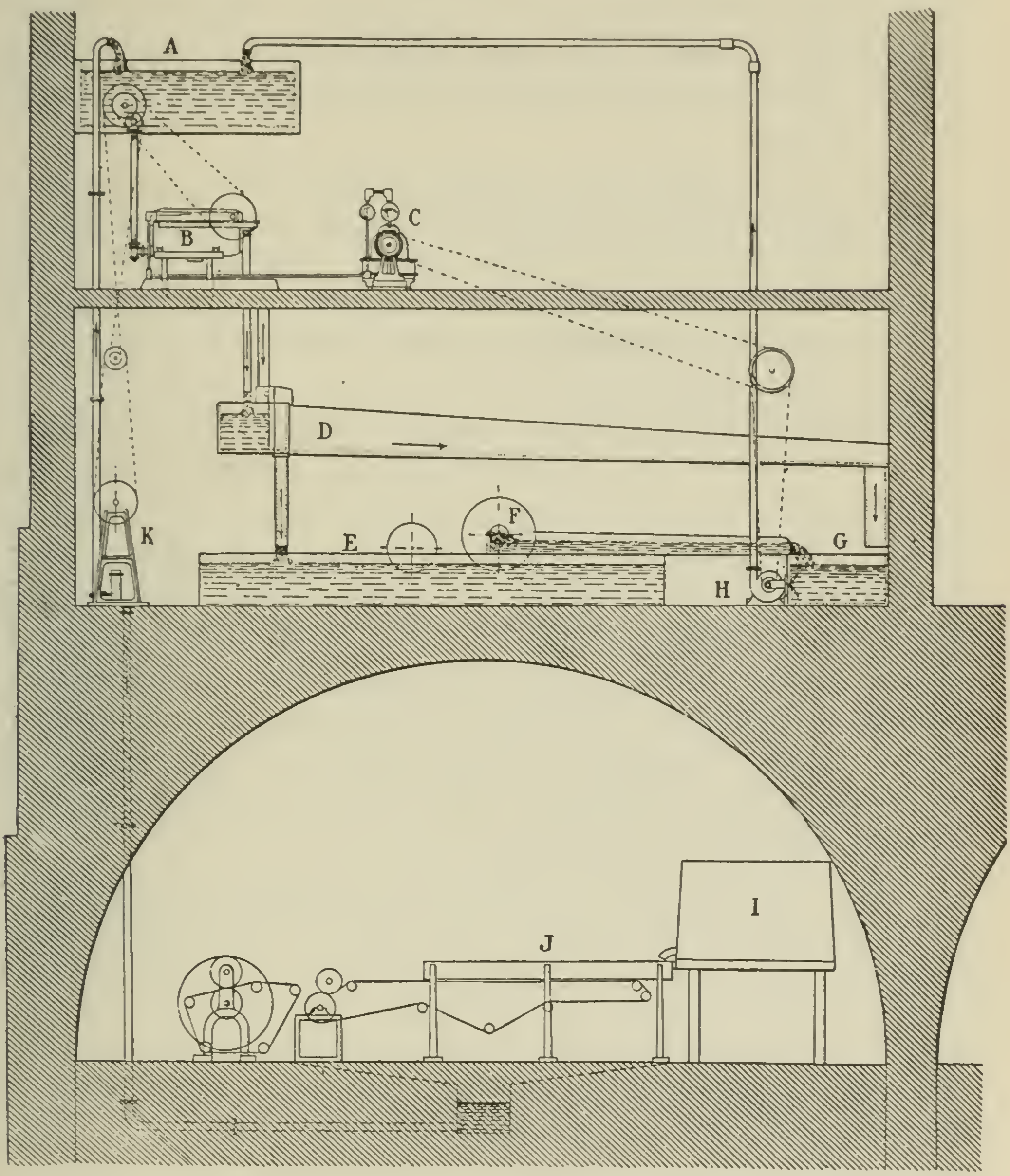

FIG. 8.

go even farther, and to affirm my full conviction that the electrolytic method will be found to afford our manufacturers the only means of meeting trade competition, and that, unless there be made some chemical discovery of very great utility and far-reaching in its results, by which the cost of bleaching by other than the electrolytic methods will be greatly reduced, the latter must become the manufacturer's only recourse.

The most important process for bleaching by means of electrolyzed solutions of alkaline earth chlorides, as I have previously mentioned, is that of Mr. Hermite, and it only remains for me to describe the method, which is to-day in actual use for bleaching wood-pulp, not only in Europe, but also in the United States.

Fig. 8 gives us a more complete view of the location of the several parts in a mill. *A* is the storage-vat for salt solution; *B*, the electrolyzer; *C*, the dynamo; *D*, trough for electrolyzed solution; *E*, the bleaching hollander, or vat; *F*, drum sieve; *G*, overflow; *H*, rotary pump; *I* and *J*, pulp machine; *K*, lifting pump for exhausted bleach liquor to supply storage-vat *A*. The apparatus will be disposed, of course, in the most convenient manner, and it is most desirable to locate the plant in such a way as to provide, as far as practicable, for a natural flow of the solution by gravity, thereby saving in pumpage.

Compared with the process of bleaching with chloride of lime, the cost by the electrolytic process is reduced by about one-half, and it should be said in favor of the electrolytic method, that it leaves a finer white upon the stock. Regarding the consumption of salts, bleached pulp, as delivered by the electrolytic method, contains from sixty to seventy per cent. of mechanically-held water. In other words, with every 100 pounds of dry pulp yielded in this process, we will have withdrawn from 150 to 230 pounds of water, which will have contained in it a certain amount of dissolved salts, and which will have to be replaced in the partially exhausted bath before being re-electrolyzed. Carrying our comparisons further, we see that the bleacher has at his command a process whereby he can obtain an effective

bleaching agent at a moment's notice, and without requiring extensive changes in his present plant; that the bleaching agent so produced is free from any residue or sediment; that it is much more complete in its bleaching action than chloride of lime; that the action on the fibres is rapid, regular, and not in any manner injurious; that it is cheap, and with a constant, or nearly constant, cost, as the raw materials are low in price.

ACTION OF A SINGLE-PHASE SYNCHRONOUS MOTOR.

BY FREDERICK BEDELL AND HARRIS J. RYAN.

[*Communicated by the authors to the Electrical Section of the Franklin Institute.*]

INTRODUCTION.

The phase relations of the different variable quantities in any alternating current problem are of paramount importance, and have often been the subject of investigation in the study of the action of the transformer. The writers of this paper have recently had occasion to study the synchronous motor with particular reference to these phase relations, and to compare polar diagrams representing the action of the motor, constructed from *a priori* reasoning, with similar diagrams obtained by experiment. The complete discussion of the action of a synchronous motor which follows, is thus verified by experiment. The polar diagrams here given, constructed from experimental data, are now published for the first time; other portions of the work have already been published in some preliminary papers,* parts of which are here included *verbatim*. The experimental

* "The Behavior of Single-Phase Synchronous Motors," by H. J. Ryan; *Sibley Journal of Engineering*, vol. viii, No. 8, May, 1894.

"An Optical Phase Indicator and Synchronizer," by G. S. Moler and F. Bedell, a paper read before the American Institute of Electrical Engineers, May, 1894; *Transactions*, vol. xi, p. 586.

"The Behavior of Single-Phase Synchronous Motors," by C. E. Hewitt and J. Lyman; *Sibley Journal of Engineering*, vol. viii, No. 9, June, 1894.

work was performed in the spring of 1894, under the direction of the writers, at Cornell University, by Messrs. J. Lyman and C. E. Hewitt, who have already published a partial report of the investigation in one of the papers already referred to.

We will first discuss the action of a synchronous motor, and will then describe the method of conducting the present investigation.

THE SYNCHRONOUS MOTOR.

The action of the commutator on a direct-current dynamo is to rectify the current induced in the armature; that is, the current from the dynamo after it leaves the brushes flows continually in one direction, although the current in the armature coils is being constantly reversed. The commutator of a direct-current motor performs the converse function. Let us suppose that we have two similar machines of this kind separately excited, and that the one is driving the other as a motor. If it so happens that the two armatures are revolving at the same speed, the two commutators may be done away with, for it is evident that the rectifying of the current by the dynamo commutator is counterbalanced by the corresponding reversal of the current by the motor commutator. The current in the coils of the motor armature flows alternately in opposite directions corresponding exactly to the flow of current in the dynamo armature. We see, then, that when the motor and dynamo are running synchronously the armature circuits may be directly connected without any commutators; that is, we have an alternating current generator driving an alternating current synchronous motor. The operation of a synchronous motor was first described by H. Wilde in a paper* read before the Literary and Philosophical Society of Manchester, December 15, 1868. The inherent regulation which maintains synchronism was referred to in this paper.

The significance of these observations was not felt at

* "On a Property of the Magneto-electric Current to Control and Render Synchronous the Rotations of the Armatures of a Number of Electro-Magnetic Induction Machines;" *Philosophical Magazine*, January, 1869.

the time, and some years later Dr. J. Hopkinson,* unaware of the earlier work, developed the analytical theory for the operation of two alternating current machines, his conclusions as to synchronous control agreeing with the observations of Wilde.

Although any alternating current generator will thus operate as a synchronous motor, it is not true that they will all thus operate equally well. The old smooth-bodied armature alternator,† with "pan-cake" armature coils, made a very poor synchronous motor, while the modern alternator, with "T-toothed" armature, fitted with machine-wound armature coils, has been found to give excellent results when run as a synchronous motor. This improved performance of the alternator as a synchronous motor is due to the increased self-induction of the armature and to the useful effects of the armature current on its own field. When the current developed by a generator is in unison with the generated E.M.F., such current exerts very little effect upon the field—neither strengthening nor weakening it. When the current lags behind the E.M.F. of the generator, the armature reaction effect that it produces upon the field is such as to weaken the field, and thus to diminish the E.M.F. produced by the generator. The reverse of this action occurs when the generator furnishes a current that is in advance of its E.M.F. This is shown to be true in the experiments which follow by the gradually increasing values of generator E.M.F. (given in the tabular data in the latter part of this paper), as the current, which at first lags behind the generator E.M.F., is brought into phase with it and

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* "On the Theory of Alternating Currents, Particularly in Reference to Two Alternate-Current Machines Connected to the Same Circuit;" *Jour. Soc. Telegraph Engineers*, vol. xiii, p. 496, 1884. At the same meeting was read and discussed a paper on "The Alternate-Current Machine as a Motor," by W. G. Adams. Further references relating to the development of the synchronous motor are given by W. M. Mordey, in his paper on "Alternate-Current Working;" *Jour. Inst. Elect. Engineers*, vol. xviii, p. 592, 1889. See also, "Long-Distance Transmission for Lighting and Power," by C. F. Scott; *Transactions Am. Inst. of Elect. Engineers*, vol. ix, June, 1892.

† We here closely follow the first paper above referred to: *Sibley Journal*, May, 1894.

finally into a position of advance. Precisely the same armature reactive effects on the field occur in a synchronous motor. There is this exception, however, that the motor E.M.F. is counter to that of the generator, so that what is a lagging current for the generator is an advance current for the motor, and the current that is in advance of the generator E.M.F. lags behind the counter E.M.F. generated by the motor. The current that strengthens the field of the generator will thus weaken the field of the motor, and *vice versa*, as will be explained later.

The speed, as is well understood, depends only on the periodicity produced by the generator and the number of poles of the motor. Neither variation of the E.M.F. impressed at the terminals of a synchronous motor, nor variation of its field excitation, will change the resulting speed so long as the motor operates at all. The armature circuits of the motor, generator and line always possess some self-induction. When, therefore, the generator pressure is higher than that of the motor at the moment when synchronism is obtained, and the machines are connected, a current will pass between the machines that will lag, because of the self-induction, behind the generator E.M.F., and will be in advance of that of the motor pressure. This current, as was just pointed out, will weaken the field of the generator and lower the E.M.F. that it generates; it will strengthen the field of the motor, and in proportion will raise its counter E.M.F. The result, therefore, is to equalize the developed pressures of generator and motor, and thus prevent a further increase of current. Such a current will have a larger component in unison with the generator pressure than with that of the motor, depending on the proportion of the electrical energy transformed into mechanical energy.

The diagram, *Fig. 1*, illustrates the action of a synchronous motor that develops a motor pressure E', equal to the generator pressure E. In this, and in all the diagrams following, positive rotation is counter-clockwise. In the case of *Fig. 1*, the circuits are assumed to have no self-induction, but to have the usual resistance. At the instant that syn-

chronism is obtained and the connection of the motor completed, there can be no current established through the motor, and, therefore, no power developed. The motor will lag in rotative speed at once to some such position as *d*, where the resultant of the motor and generator pressures is *ac* or E''. Since there is no self-induction in the circuit, the resulting current, *I*, is in unison with E''. Such a current has component values in unison with the generator and motor pressures that are equal. No power can, therefore, be developed, and the motor would promptly come to a standstill.

The conditions represented by *Fig. 2*, are, that the generator pressure is greater than the motor pressure, and that the circuits possess resistance but no self-induction. At the moment that the motor is synchronized and connected, a current will be established that is in unison with the generator pressure and opposite to that developed by the motor. The developed power that thus results is, in general, more than sufficient to keep the motor running light at synchronism. The speed position of the armature is, therefore, advanced to a point *d*. Here is obtained a resultant E.M.F., E'', that, since there is no self-induction, establishes a current which is in unison with the resultant E.M.F., E''. The component *ae* along *E* is here greater than the component *af* in the direction of the motor E.M.F., E'. A balance occurs at that point where the power developed is just sufficient to keep up the synchronous speed of the motor armature, and no further acceleration takes place. On loading down the motor its armature position is retarded. The maximum load that the motor will stand is that at which the product of the motor pressure into the component of the current that is in unison with it, is a maximum. This the diagram plainly indicates to be at the point of true synchronism. When this point is reached an increase in the load will further retard the armature, and the above product will again diminish; the motor, being overloaded, will come quickly to rest.

In *Fig. 3*, *E* and E' are equal, the armature and line circuits have no appreciable resistance, and self-induction is

present. At the instant of synchronism and connection of the motor to the generator circuit, no current will be established through the motor, because the generator and counter E.M.F.s are equal. The motor armature will lag to a point where the resultant pressure is E''. E'' will establish a current I, one-quarter of a period behind itself. Such a current will have a large component that is negative with respect to the motor pressure and in unison with that of the generator. An early point is reached at which the motor will do good work. Later on a maximum component of this current, that is opposite to the motor pressure, will be found, beyond which the motor will lose synchronism.

In *Fig. 4*, the generator E.M.F., E, is greater than the motor E.M.F., E'. The circuits possess self-induction, but no resistance. At the instant that the motor is synchronized and connected, the resultant pressure, E'', is the algebraic difference between E and E'. Inasmuch as the circuit possesses self-induction with no resistance, E'' will establish a current through the motor at right angles to itself and the motor and generator pressures. From such a current no power can result. The armature will lag to a later position, where the conditions are found to be practically the same as those discussed in connection with *Fig. 3*.

In *Fig. 5*, E equals E', and resistance and self-induction are both present in the circuits. Since E and E' are equal, no work can be done until the armature lags to some position, d, where the resultant E.M.F. is E''.

When the E.M.F., resistance, self-induction, and periodicity of a circuit, are known, the impedance is known, and the current becomes known from the relation

$$\text{Current} = \frac{\text{Resultant E.M.F.,}}{\text{Impedance}}$$

The phase position of the current is determined by the relation between the resistance and the reactance of the circuit. The projection of I upon E' is a quantity that is proportional to the developed mechanical power. This projection, as in all other cases, at a certain position attains a maximum beyond which the motor will come to rest.

In the next diagram, *Fig. 6*, E is greater than E', and self-induction and resistance are present. In general, the position of the armature at no load will be in advance of the normal position of synchronism, the position of advance being limited, as in the similar cases cited above, and which the figure fully illustrates.

In practice, the relations of the magnitudes of E and E' are determined by the field excitation and the currents that are established through the motor. Armatures that develop powerful reactive effects upon their fields, in action equalize the motor and generator pressures, and such armatures must necessarily possess considerable self-induction. These are the requirements for suitable working, as indicated by the above analysis.

It is well to suggest, also, that the amount of the mass of the revolving parts of a synchronous motor has an additional effect upon the stable operating conditions. During every complete period, there are two short intervals, throughout which the motor, in general, must act as a generator and give back a small amount of power to the generator. The only source of this power is the fly-wheel property of the revolving parts of the motor. Multiphase motors are independent of this fly-wheel effect, because at no instant does the motor do work on the generator, while on the other hand, the amount of mechanical energy developed instant after instant is practically uniform.

THE PHASE-INDICATOR.

In the experimental investigation of the synchronous motor, the Bedell-Moler phase-indicator* was employed to determine the angular difference in the position of the armatures of the motor and generator. The shafts of the motor and generator were placed in line, abutting, but not quite touching. The phase-indicator consists of two metal disks, each fastened to a collar made to slip on the adjacent ends of the two armature shafts, and held in position by

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* *Loc. cit.*

set-screws. These disks are of zinc, one-thirty-second of an inch thick, nine inches in diameter, and about one-quarter of an inch apart. In the disks are curved slits, about one-twentieth of an inch wide, extending from points near the hub almost to the circumference. In this case—the motor and generator having eight poles—there were four slits in each disk, one slit corresponding to each pair of poles, or to the number of complete periods in one revolution. The direction of curvature of the slits in one disk is opposite to that in the other, so that the slits of one cross those of the other; otherwise, the two disks are in every way similar. The intersection of the slits forms an opening that will allow a beam of light from an incandescent lamp, placed at one side, to pass through. Each slit extends over a complete period, from its inner to its outer end; therefore, one of the armatures must move, with reference to the other, through a complete period, to cause a spot of light to travel through this range. *Fig. 7* makes this more clear. If the two armatures are revolving at the same speed, or synchronously, the intersections of the slits remain at a fixed distance from the center, and we see, in consequence, a ring of light. If one revolves faster than the other, the ring of light moves either towards the center or towards the circumference of the disk. These slits are so constructed that the distance to or from the center, traversed by the intersections of the two sets of slits, is proportional to the change in the relative angular positions of the two armatures.

The curvature of the slit is that of the spiral of Archimedes, and was constructed as follows: Each quadrant was divided into eighteen equal sectors. Nineteen concentric circles were then drawn with a sharp tool on the face of the disk, thus dividing the portion of the disk lying between the extreme limits desired for the slit, into eighteen annuli, each about three-sixteenths of an inch wide. The slit represents a complete period of 360°; therefore, the widths of the sectors and annuli represent 20°. The points of intersection of the corresponding radii and circles give the location of the slits.

The position of the ring of light indicates the relative positions of the two armatures. This position was observed in a mirror set at an angle of 45° with the plane of the disks, and arranged with a scale reading in degrees corresponding to the scratched circles on the disk. An observer could thus see, in the mirror, the reflected ring of light and the phase position which it indicated. The disks were set so that the outer ends of the slits were adjacent when the two armatures stood on their corresponding neutral points, the positions being determined by the ballistic galvanometer method of field exploration. With the armature on the neutral point, no throw of the needle of a ballistic galvanometer connected to the brushes is obtained, when the field current is reversed.

In operation, the ring of light shown by the phase-indicator would vibrate, more or less, according to the stability of the motor. This vibration was small, when the motor was operated under the most favorable conditions; but with unstable conditions, it would vibrate, at times, as much as 30° on each side of the mean, before the motor would go out of synchronism.

The present investigation has shown the phase-indicator to be, in all respects, an efficient instrument.

THE GENERATOR AND MOTOR.

Two small Westinghouse alternators, of the same size and shape, designed to supply ten incandescent lamps, were used as generator and motor. Before being thrown into direct connection with the generator, the motor was brought to speed by means of a direct current-starting motor, to which it was belted. A half horse-power Edison machine was used for this purpose. When synchronism was reached, the direct current supplying this starting motor was broken at the instant that the alternate current motor was connected to the generator.

The magnetization curve for the alternate current motor was found to be practically a straight line, as shown by the following readings, which are corrected for a normal speed of 2,080 revolutions per minute:

DATA FOR MAGNETIZATION CURVE OF MOTOR.

Current in Motor Field.	E.M.F. at Brushes.	Speed.
1·	9·9	2,080
1·5	16·7	"
2·	22·7	"
2·5	28·7	"
3·	34·5	"
3·5	40·5	"
4·	46·4	"

The stability of a synchronous motor depends largely upon the field excitation and the amount of the self-induction in the armature circuit. With no added self-induction in the armature circuit the motor in the present case was found to be quite unstable. Curve *A*, *Fig. 8*, shows the relation between the current flowing through the motor and generator armatures and the exciting current of the motor field, when no added self-induction was in the armature circuit. The motor was driving the small Edison machine on open circuit as a light load. The generator field excitation was kept constant at 3·5 ampères; the speed was 2,080 revolutions per minute. The extreme range through which the motor could be kept in synchronism was from a motor field current of from 1·5 to 3·3 ampères. With a motor field excitation of 3 ampères, the armature current was a minimum. The operation under these conditions, however, was quite unstable, and a light load would throw the motor out of synchronism, and thus cause it to stop.

The stability was increased by the addition of self-induction to the armature circuit, and for this purpose a coil without iron was employed. Curves *B* and *B'*, *Fig. 9*, show the relation between the motor excitation and armature current, as was shown by curve *A*, for the preceding case without added self-induction. The motor ran synchronously with a field excitation varying from ·6 to 2·2 ampères, and from 3 to 3·6 ampères, but would not run with an exciting current between 2·2 and 3 ampères. With the weak field excitation, a large current was consumed by the motor, while with the strong excitation current, a much smaller current was taken by the motor. This may be attributed to the phase position which the current takes in the two cases, with reference to

the phase position of the impressed E.M.F., as is shown by the polar diagrams for such cases.

It was found that by gradually increasing the self-induction in the armature circuit, the two parts of the curve B and B' were brought together. The self-induction was increased by inserting in the coil an iron core consisting of a bundle of iron wire. At a certain position of this core the self-induction of the armature circuit was such that the motor consumed a much smaller current than at any time before, ran with great stability, and through a wide range of field excitation, as shown by curve C, *Fig. 10*, which will be discussed later. The final run was made under these conditions.

The coëfficient of self-induction of the motor armature was found to be 0·00032 henrys, and that of the induction coil with the iron core, 0·00168 henrys. The total self-induction was, therefore, 0·002 henrys. The total ohmic resistance of the armature circuit and connections measured 0·31 ohms. The self-induction of the armature was measured for different field excitations and for different currents, the mean of all the values obtained being averaged and taken as constant. The excitation of the field seemed to make no appreciable difference in the coëfficient of self-induction of the armature. The resistance and self-induction of the armature circuit vary somewhat with the value of the current flowing, on account of temperature changes and the saturation of the iron, but the error introduced by considering these constant is small. From these measurements the reactance and impedance were determined.

THE METHOD OF EXPERIMENT.

Throughout the following investigation, the generator was run at a nearly constant speed of about 2,080 revolutions per minute, and with a constant field excitation of 3·5 ampères. The motor was brought up to speed by the small Edison starting motor mentioned above, and thrown into circuit at the instant when its phase position, as indicated by the ring of light of the phase-indicator, remained 180° behind that of the generator. The small Edison machine

was then driven on open circuit as a light load for the alternate current motor, this being the only load throughout all the experiments here described. The exciting current of the motor field was changed by increments of 0·2 ampères between the limits 1·8 and 6 ampères. The motor and generator field currents were obtained from a storage battery, and were accordingly quite constant.

The quantities required were:

The impressed E.M.F. (E) of the generator;

The counter E.M.F. (E') of the motor;

The resultant E.M.F. (E''), which is the resultant of the impressed and counter E.M.Fs;

The armature current (I''');

The angle of lag (ϕ) of the current behind the resultant E.M.F. (E''); and

$$2\,\pi \times \text{frequency} = \omega = \frac{2\,\pi \times 4 \times \text{r.p.m.}}{60}$$

The above quantities are required in order to construct the graphical diagrams which show the complete action of the synchronous motor.

The following quantities were likewise obtained:

Generator field current (I').

Motor field current (I'').

Disk reading, angle ϕ.

The currents were measured directly by means of a Siemens' dynamometer. The impressed E.M.F. (E) of the generator was obtained from a voltmeter connected to the generator brushes. The counter E.M.F. of the motor was taken directly from the magnetization curve for the motor plotted according to the table given above, no correction being made for armature reactions.

The electromotive forces E, E' and E'' must all be in equilibrium when the motor is running. The motor, when running in synchronism, will take such a phase position with respect to the generator that this relation is obtained. The resultant E.M.F. (E'') is then just sufficient to overcome the product of the current (I''') and the impedance of the armature circuit. Therefore:

$$E'' = I''' \times \text{impedance.}$$

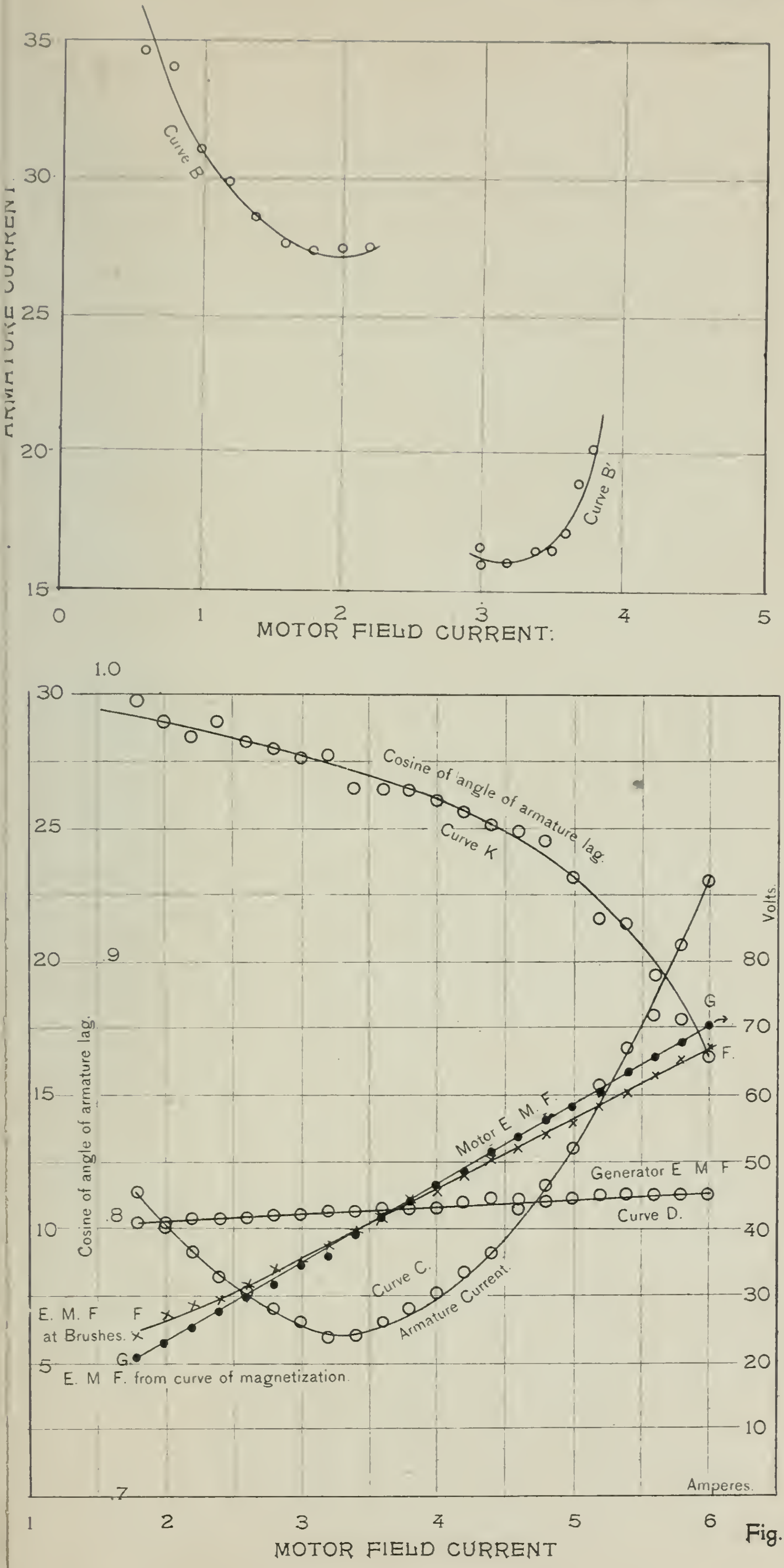

ARMATURE CURRENT.
Curve B
Curve B'
MOTOR FIELD CURRENT.
Cosine of angle of armature lag.
Curve K
Volts.
G
F.
Motor E. M. F.
Generator E. M. F.
Curve D.
Curve C.
Armature Current.
E. M. F. F
at Brushes.
G.
E. M. F. from curve of magnetization.
Amperes.
MOTOR FIELD CURRENT

Fig. 10.

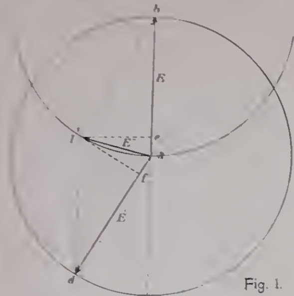


Fig. 1.

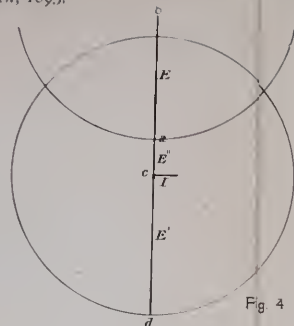


Fig. 4

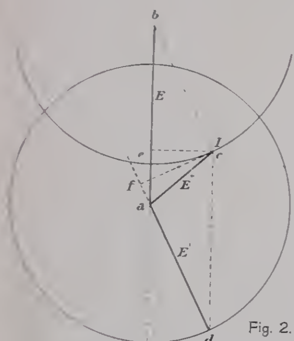


Fig. 2.

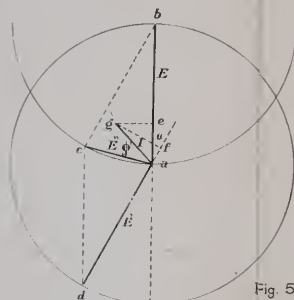


Fig. 5.

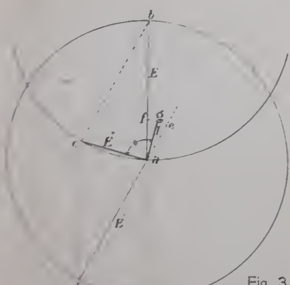


Fig. 3

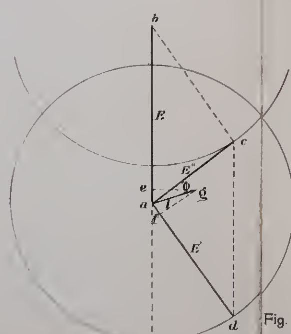


Fig. 6.

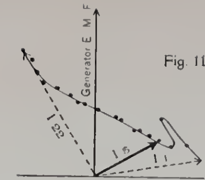


Fig. 11.

Locus of the direction and magnitude of the armature current

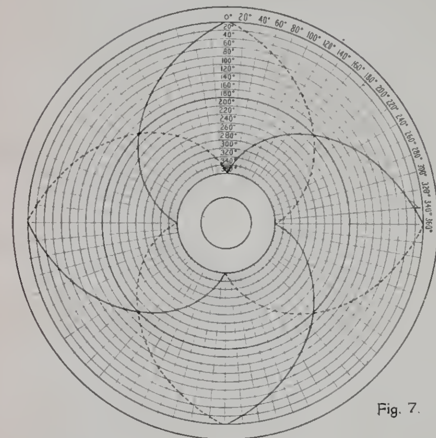


Fig. 7.

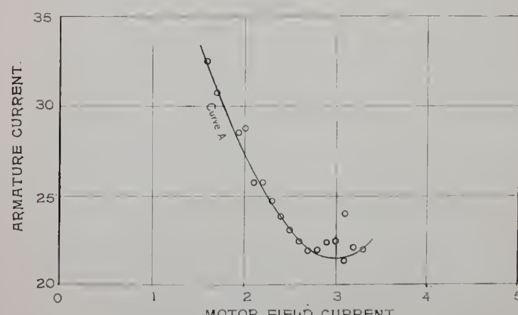


Fig. 8.

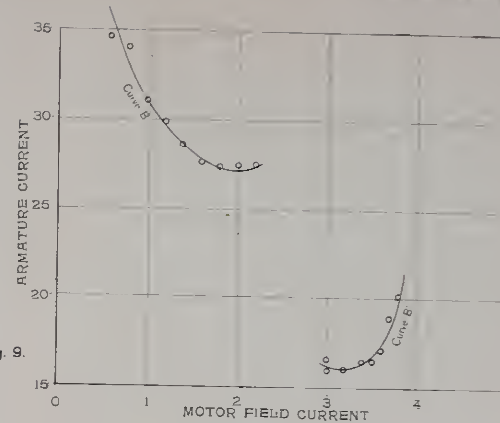


Fig. 9.

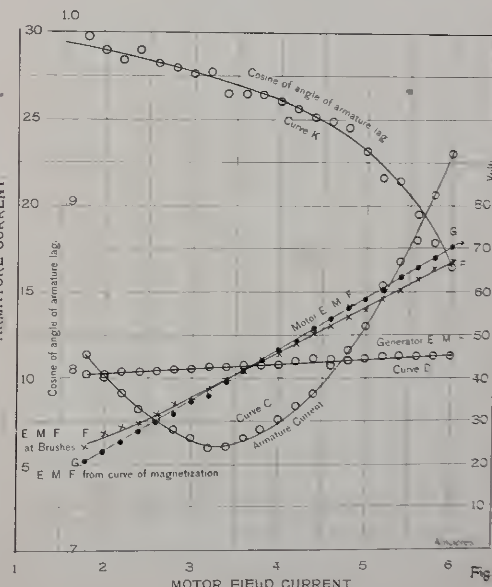
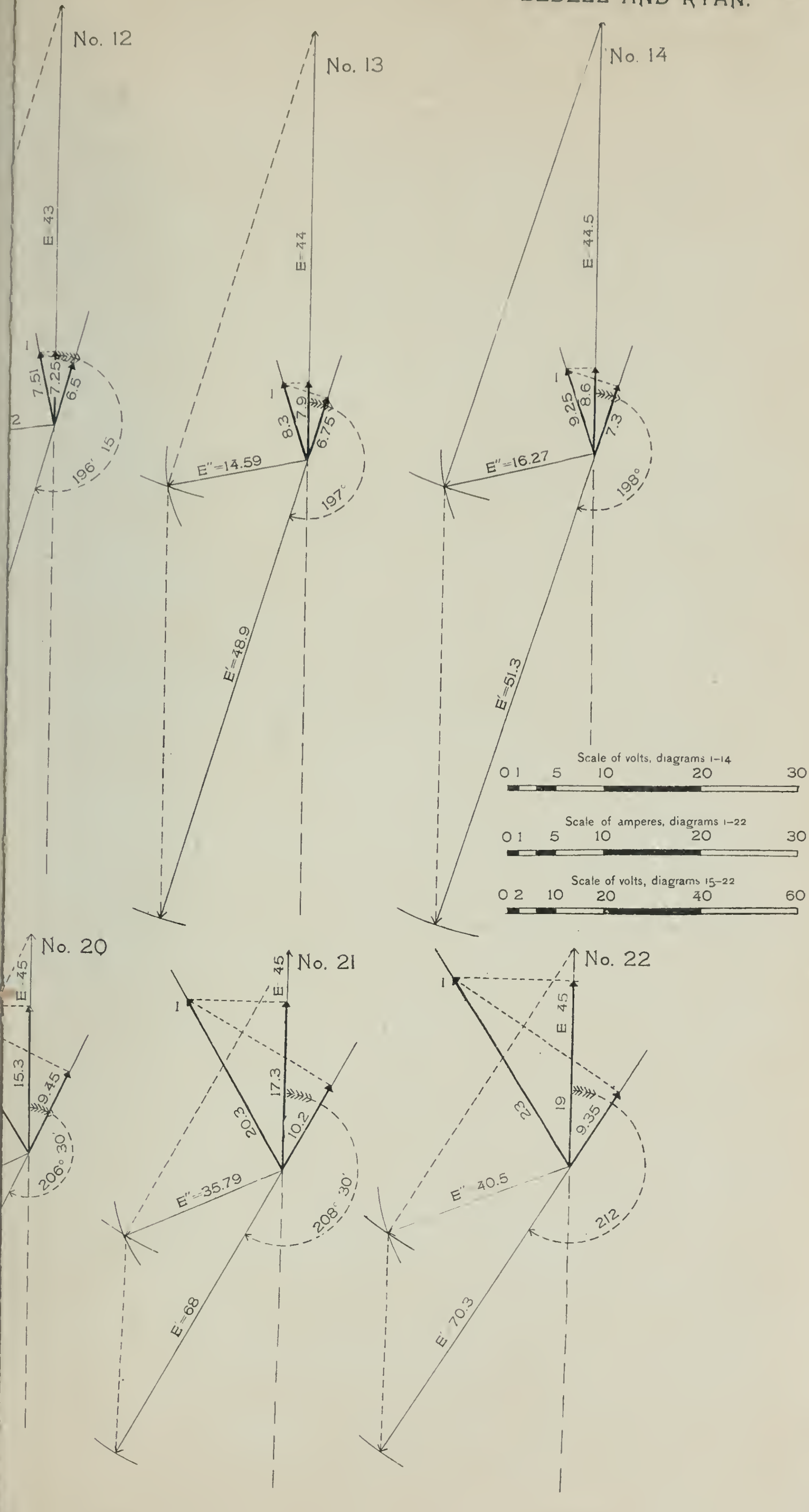


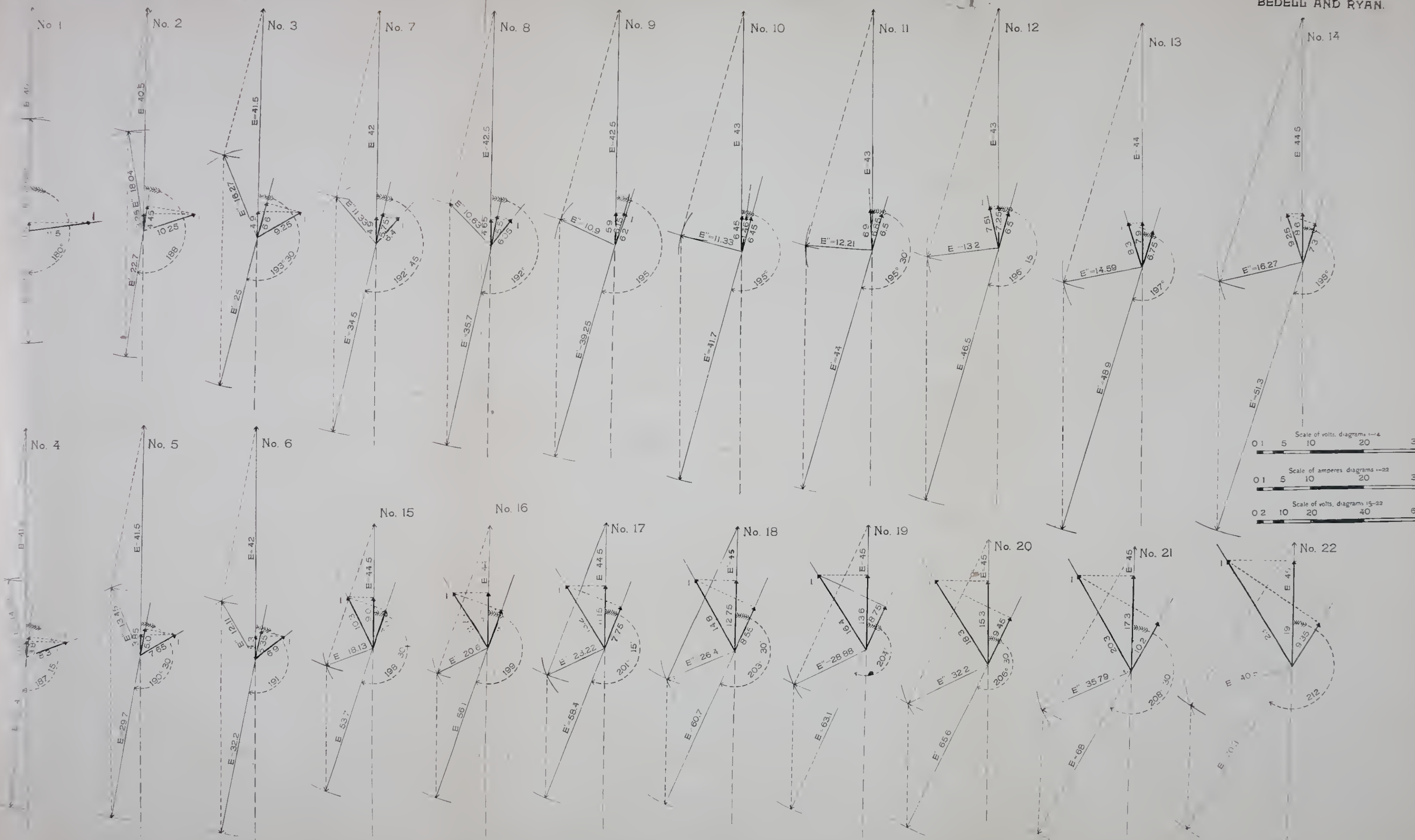
Fig 10.

THE SYNCHRONOUS MOTOR (Bedell and Ryan.)


No. 12
E 43
7.51
7.25
6.5
196° 15'
No. 13
E 44
8.3
7.9
6.75
E''=14.59
197°
E'=48.9
No. 14
E 44.5
9.25
8.6
7.3
E''=16.27
198°
E'=51.3
Scale of volts, diagrams 1–14
0 1 5 10 20 30
Scale of amperes, diagrams 1–22
0 1 5 10 20 30
Scale of volts, diagrams 15–22
0 2 10 20 40 60
No. 20
E 45
15.3
9.45
206° 30'
No. 21
E 45
17.3
20.3
10.2
E''=35.79
208° 30'
E'=68
No. 22
E 45
23
19
9.35
E'' 40.5
212
E' 70.3

Jour. Frank. Inst., Vol. CXXXIX March, 1895.

BEDELL AND RYAN.



SYNCHRONOUS MOTOR DIAGRAMS. (Bedell and Ryan.)

The E.M.F. is thus computed: The angle of lag of the current behind the resultant E.M.F. is

$$\phi = \text{arc tan.} \frac{\text{reactance}}{\text{resistance}}.$$

The resistance and self-induction being taken as constant, we have, therefore, a constant value for the angle ϕ, viz.: 82·5° (the speed varying little during the run, and ω being taken, therefore, as constant).

The phase position of the motor with respect to the generator is represented exactly by the phase positions of their respective E.M.F.s. The relative phase position of these E.M.F.s was determined by graphical construction, as in *Fig. 5*. The generator and motor E.M.F.s and their resultant being known, their position is determined by a construction analagous to the parallelogram of forces. In *Fig. 5*, *ab* represents the direction and magnitude, taken in any convenient scale, of the generator E.M.F.; *ad*, the motor E.M.F., as taken from the magnetization curve; *ac*, the resultant E.M.F. The magnitudes of the E.M.F's. being known, their relative positions are thus determined. The angle between the resultant E.M.F., *ac*, and the current, being determined as described above, *ag* may be drawn to represent the current. The diagrams, Nos. 1–22, are thus constructed:

The angle *bad* measured backward (or clockwise) shows the phase position of the motor armature with respect to the generator armature, and it should agree substantially with the disk reading of the phase indicator.

The energy in watts delivered by the generator to the circuit is equal to the product of the impressed E.M.F. (E) and of *ae*, which is the component of the current *ag* in line with the impressed E.M.F.

The energy in watts transformed into mechanical power by the armature is equal to the product of E' and of *af*, the component of the current *ag* in line with E'. This product must be negative in value, showing energy consumed and not produced, for the machine to run as a motor. The mechanical power developed is expended in driving the Edison machine on open circuit, and in journal friction, hysteresis and

foucault currents. The iron losses increase as the field excitation is increased. The difference between the watts delivered and the watts transformed into mechanical power is equal to the RI^2 losses of the armature circuit. Thus, from the fifth observation (see Diagram 5), we have:

$$\text{Watts input} = 41{\cdot}5 \times 3{\cdot}85 = 160.$$
$$\text{Watts mechanical power} = 29{\cdot}7 \times 5{\cdot}0 = 148.$$
$$\text{The } RI^2 \text{ losses} = 160 - 148 = 12 \text{ watts.}$$

In the accompanying table, the observed data are given to the left of the double line, and the computed results to the right. No measurements were made with a motor field current above six ampères, on account of the possibility of springing the armature shaft; it is to be supposed that the motor would run synchronously beyond this point.

The results given in the table are likewise shown in *Fig. 10*, and in the diagrams Nos. 1-22. In *Fig. 10*, curve *C* shows the armature current for different field excitation; the current becomes less and less as it comes into phase with the impressed electro-motive force, and then increases as it takes a position in advance of the electro-motive force. That there is a point of minimum current and a maximum power factor was shown by Mr. Mordey, in a paper read before the Institution of Electrical Engineers,* in which he gave a curve for the armature current at light load, such as curve *C*, *Fig. 10*. He further showed that the motor E.M.F. could be higher than the generator E.M.F., as is clearly brought out by the present paper. This point was predicted in 1884 by Dr. Hopkinson in his paper† before the Institution of Electrical Engineers, on "The Theory of Alternating Currents." In the discussion, Mr. Kapp‡ showed such curves for several loads, showing the forms these curves would take, both with and without armature reactions. His curves were plotted with abscissæ representing the counter E.M.F. of the motor. The counter E.M.F.

* "On Testing and Working Alternators," *Journal of the Institution of Electrical Engineers*, Feb. 23, 1893; see also London *Electrician*, Vol. xxx, p. 545.

† *Loc. cit.*

‡ London *Electrician*, Vol. xxx, p. 575.

Observed.								Computed.						
Number of Observation.	I', Generator Field Current.	I'', Motor Field Current.	I''', Main Current.	E, Generator E.M.F.	E.M.F. at Motor Brushes.	Reading of Phase Indicator: Angle θ.	Speed.	E', Motor E.M.F.	E'', Resultant E.M.F.	Computed Angle θ.	Watts Input.	Watts Transformed into Mechanical Power.	RI^2 Losses of Line and Motor Circuit in Watts.	Computed RI^2 Losses in Watts.
1	3·5	1·8	11·5	40·5	24·	185°	2,088	20·2	20·23	180°	61	32	29	28·
2	3·5	2·0	10·25	40·5	27·	187°		22·7	18·04	188°	131	101	30	22·
3	3·5	2·2	9·25	41·5	28·5	190°	2,088	25·	16·27	193·5°	201	165	36	18·
4	3·5	2·4	8·3	41·5	29·5	190°		27·4	14·59	187·3°	126	104	22	14·4
5	3·5	2·6	7·65	41·5	31·5	190°	2,085	29·7	13·45	190·5°	160	148	12	12·3
6	3·5	2·8	6·9	42·	34·	190°		32·2	12·11	191°	180	172	8	10·
7	3·5	3·0	6·4	42·	35·5	195°	2,095	34·5	11·33	192·7°	206	197	9	8·6
8	3·5	3·2	6·05	42·5	37·5	193°		35·7	10·63	192°	197	196	1	7·7
9	3·5	3·4	6·2	42·5	39·5	198°	2,080	39·25	10·9	195°	250	240	10	8·1
10	3·5	3·6	6·46	43·	41·5	198°		41·7	11·33	195°	2 8	269	9	8·8
11	3·5	3·8	6·9	43·	44·	198°	2,080	44·	12·21	195·5°	294	286	8	10·
12	3·5	4·0	7·51	43·	45·5	200°		46·5	13·2	196·3°	312	302	10	11·8
13	3·5	4·2	8·3	44·	48·	200°	2,090	48·9	14·59	197°	348	336	12	14·4
14	3·5	4·4	9·25	44·5	50·	200°		51·2	16·27	198°	382	374	8	18·
15	3·5	4·6	10·30	44·5	52·	200°	2,075	53·7	18·13	198·5°	401	376	25	22·4
16	3·5	4·8	11·7	44·	54·	200°		56·1	20·6	199°	427	392	35	28·8
17	3·5	5·0	13·2	44·5	55·8	200°	2,075	58·4	23·22	201·3°	496	455	41	36·6
18	3·5	5·2	14·8	45·	58·5	205°		60·7	26·4	203·5°	568	519	49	46·
19	3·5	5·4	16·4	45·	60·5	205°	2,070	63·1	28·88	204°	613	552	61	57·
20	3·5	5·6	18·3	45·	63·	208°		65·6	32·2	206·5°	689	619	70	70·2
21	3·5	5·8	20·3	45·	65·5	215°	2,070	68·	35·79	208·5°	778	694	84	87·
22	3·5	6·0	23·	45·	67·	220°		70·3	40·5	212°	855	657	98	111.

of the motor was not directly proportional to the exciting current, for his curve of magnetization was not a straight line. Mr. Steinmetz* has determined these curves analytically, plotting them from a quartic equation showing the relation between armature current and motor E.M.F. He assumes a constant reactance and the absence of armature reactions. His theoretical curve for no load (where no load means the absence of friction and of all energy expenditure) meets the X-axis at a sharp point, which would show that when the motor was doing absolutely no work, the armature current would actually be brought to zero, for a particular value of the field current. His curve for light load corresponds approximately with curve *C*. It is, however, constructed for a constant load, whereas the load in the present investigation became greater as the hysteresis losses increased with the excitation.

The increase in the generator E.M.F. on account of armature reactions, although the speed and excitation were constant, is shown in curve *D*, *Fig. 10*. That armature reactions have the opposite effect in the motor, as mentioned earlier in this paper, is shown by curves *F* and *G*, which represent, respectively, the E.M.F. observed at the brushes of the motor, and that obtained from the curve of magnetization. With a small field excitation, the armature current, which is a lagging current with reference to the generator E.M.F., is one of advance with reference to the motor E.M.F.; and the armature reactions are, therefore, such that the E.M.F. at the brushes of the motor is greater than that obtained from the curve of magnetization. With a larger field excitation of the motor, the armature current is one of advance with reference to the generator E.M.F., and a lagging current with reference to the motor E.M.F., which causes the E.M.F. at the brushes of the motor (curve *F*) to be less than that obtained from the magnetization curve, as shown in curve *G*. The rise in the generator E.M.F., due to armature reactions, corresponding to this decrease in

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* "Theory of a Synchronous Motor," *Transactions of the American Institution of Electrical Engineers*, Oct. 17, 1894.

motor E.M.F., due to the same cause, is shown in curve *D*, as already explained. These curves have not been corrected for the fall of potential due to the impedance of the armature; but the results are quite striking and are in accordance with the explanation given in the early part of this paper, to the effect that the armature reactions in the generator and motor assist in the self-regulation of the plant. The gradual change in armature lag is shown by curve *K*.

Diagrams, Nos. 1–22, are drawn for each corresponding set of readings given in the table. The current, represented by the heavy arrow *I*, lags behind the generator E.M.F. when the field excitation of the motor is weak. The motor thus produces the effect of self-induction in the circuit.

As the excitation is increased, the current comes more and more into phase with the E.M.F., and finally comes into phase with it. The armature current is now a minimum. A further increase in the field excitation advances the armature current ahead of the E.M.F.; that is, the motor now acts the same as a capacity, or condenser, in a circuit, this capacity-effect increasing as the field excitation increases.

In a recent paper* on "Some Advantages of Alternate Currents," Prof. S. P. Thompson lays particular stress on this condenser action of an over-excited synchronous motor, and emphasizes the fact that synchronous motors may advantageously be operated in parallel with transformers, to overcome the effects of self-induction. We have experimented at length upon the action of condensers in parallel with transformers,* and the advantages to be obtained by this system of operation. Inasmuch as the transformer tends to make the current lag, and the condenser tends to place the current in advance of the E.M.F., it is possible to obtain such a balance between the two that the line current will be in phase with the electro-motive force. Under these circumstances a certain amount of power is transmitted

* British Association, Oxford, 1894.

* See Hedgehog Transformer and Condensers, *Transactions of Institute of Electrical Engineers*, Vol. x, p. 497.

with a minimum current. The polar diagrams, in the present paper, show conclusively that the condenser action of over-excited synchronous motors will enable them to be operated in the same way as were the condensers in the paper referred to.

The changes in the magnitude and direction of the armature current, as the field excitation changes, are clearly seen in *Fig. 11.* The current for the first observation (compare Diagram 1) for the weakest field excitation, has the position I_1. As the field excitation increases, it takes successively the positions indicated by points, coming into phase with the E.M.F., and finally in advance of it, as shown in the position I_{22}, corresponding to the last observation (see Diagram 22). The heavy arrow I_5 represents the current for one particular observation. The locus for the armature current is obtained by drawing the curve through the successive points. With a constant E.M.F. the distance of any point of this curve above the horizontal would be proportional to the power given the motor. With a constant E.M.F. and constant power supplied to the motor, the curve would be a horizontal straight line. The rise in the curve at the left is due to the increased power, necessary in this case as the field current of the motor is increased. The irregularity in the curve at the right is due to the instability of operation during the first few observations.

In constructing the polar diagrams, the values of θ, the angle of lag of the motor armature, as obtained by the readings of the phase-indicator, were not employed. From the diagrams constructed as described above, the value of the armature lag was obtained as given in the column headed "Computed Angle θ," which is seen to agree closely with the armature lag as shown by the phase-indicator. The accuracy of the work and the correctness of the reasoning were thus completely verified by the phase-indicator readings.

The polar diagrams, here shown for the first time, thus simply show the complete action of the synchronous motor.

CORNELL UNIVERSITY, December, 1894.

WATER PURIFICATION.*

BY RUDOLPH HERING.

[*Concluded from p. 144.*]

We now come finally to the process of purification by *filtration*, which is more effectual than any of those hitherto mentioned in effecting a permanent removal of the impurities. It allows the water to pass through a porous material which, first, on account of the straining action of its pores, frees it from suspended particles which have made it turbid. Then, owing partly to a chemical purification and partly to the action of living bacteria, the dissolved organic matter is transformed into nitrates or mineral compounds. This transformation is effected by reason of the large interstitial area existing in the many pores of the filtering material.

We may divide the processes into two classes: those where the filtration is *rapid*, and those where it is *slow*. In the former case we obtain merely a clarification of the water, because a certain time and special conditions are necessary to allow of a complete destruction of the organic matter by the filter, which conditions are fulfilled only by slow filtration.

In the case of *rapid* filtration, the pores are continually filled with water flowing through them under more or less pressure. When the pores are of nearly equal size, as for instance in the Pasteur filter, or in filters made of certain other artificially prepared materials, there obtains a nearly fixed relation between the amount of clear water produced and the pressure exerted upon the filter. But where the pores are of unequal sizes, an increased pressure is apt to force out the retained substances from the smaller into the larger pores, and thus, to some extent, to allow them to escape and leave the water in a less clear condition. Filters of natural gravel, where the pores are of different sizes, have

* A lecture delivered before the Franklin Institute, February 2, 1894.

been known to run quite turbid for a while after the pressure upon them has been increased. The degree of clearness depends upon the degree of fineness of the pores, and the finer the pores the greater will be the pressure necessary to deliver the same quantity of clear water.

We have, therefore, a fixed relation between the degree of clearness of the water, the fineness of the material, the pressure of the water when passing through the filter and the quantity of clear water delivered by it. The action of rapid filtration is almost wholly mechanical, so far as practical purposes are concerned.

The first action of a filter is to retain the coarse particles of suspended matter upon the surface. Some of them enter the pores for a short distance and these particles themselves, when lodged, act as a filtering material and assist in straining out the finer particles. The most effective part of the filter is, therefore, that near its surface.

The accumulation of the finer particles gradually causes the filter to become obstructed; and, if the filter is to remain efficient, these retained particles must be periodically removed. The depth of material necessary for efficient filtering depends on its fineness; the finer it is, the shallower the filter may be.

The pores of a filter are not fine enough to remove the bacteria by straining. In all systems of rapid filtration they are retained only by a film which is gradually formed on the surface of the filter, either by the accumulation of organic matter or by a coagulant in the water. As it always takes some time for this film to form, and as its continuity can readily be destroyed at any time, it offers no security against the possible reappearance of a large proportion of the bacteria in the effluent water.

Regarding the materials which are used for rapid filtration we may classify them as being fibrous, granular and porous.

The fibrous material used for filters consists of felt, cloth, straw, cotton, or the like. The use of sponges is also common. Mineral wool made of fine spun glass is likewise used.

The granular materials are such as sand, gravel, finely-broken stone, charcoal, coke, cinders, and some artificial materials for which special advantages are claimed.

Porous material may be unglazed porcelain, burnt clay, certain volcanic minerals, or some artificial product. But porous stone soon becomes clogged, and then it is almost impossible to clean it. It is useful only when its pores are very fine, so that the matter which is strained out is kept so near the surface that it can be removed by washing.

Some filtering materials act also chemically upon the matter which is dissolved in the water; for instance, animal charcoal will absorb gases, such as oxygen, nitrogen, carbonic acid and sulphuretted hydrogen, and will remove some mineral salts. It will also destroy some of the albuminous compounds, as is proven by the fact that free ammonia and nitrates are found in the effluent water. Both of these are formed by decomposition while the water is passing through the charcoal. Charcoal is known to be more effective than sand in removing dissolved substances, particularly at first, and also in removing coloring matters contained in the water. But it is not as permanent in its operation, and its efficiency ceases in time.

Experiments made with fine charcoal and coke for rapid filtration, show that besides acting as a strainer, and besides having a very slight chemical action, they have removed, for several days at a time, over ninety-five per cent. of the bacteria contained in the water. They are specially well adapted for rapid filtration, because, after they have become charged with organic matter, they can be dried and will have lost but little of their original value as fuel.

We shall now describe a few appliances which have been used for the rapid filtration of water. Among filters used in the household, we may mention the Pasteur filter as one of the best. This consists of tubes made of unglazed porcelain, so arranged that the water, introduced into a compartment where these tubes are erected, filters into them, the clear water being drawn out from the bottom. It has been found that this material is, for a considerable time, highly efficient in keeping out all living organisms, but it

should not be forgotten that the tubes need frequent cleaning, as a slimy coat forms on the outside and eventually impairs the effectiveness of the filter. Besides cleaning them periodically, the frequency of the period depending on the character of the water and upon the quantity used, they should occasionally receive a boiling, so that any bacteria that may have entered the material may be destroyed.

Other efficient forms of domestic filters use charcoal or coke as their filtering material. Others have fine sand and some have finely divided iron. The difference in their value depends upon the proper disposition of the materials and upon the facilities for cleaning them. All such house filters very soon lose their efficiency by becoming clogged. To insure a fair degree of healthfulness of the water, it is almost essential to have them cleaned once a day, even though the water still runs clear. This may be necessary merely with regard to the surface layers, the entire filter being cleaned at longer intervals. There are, in the market, filters so arranged that, whenever desired, they can very easily be cleaned, by merely reversing the current of water. This drives out the suspended matter which has been collected, and washes the material. Such filters, while generally more expensive, are vastly superior to those which do not allow of such frequent washing.

As already mentioned, a filter is improved in its action by adding to the water a precipitant. Attachments can be added to most filters, which allow a certain amount of alum, and, perhaps, other precipitants to be mixed with the water, and thus cause a coagulation of the organic matter, which is thereby more easily retained and itself assists in retaining also large quantities of microbes.

Among the larger filters we may mention those furnished by the New York Filter Company and others, and used extensively in our own country. They are built according to various patterns, as the circumstances may require. These filters act in a similar manner to those already mentioned. The filtering material generally consists of fine sand or coke.

The apparatus of Andrew Howatson for softening very hard water, is somewhat extensively used in England and France. The softening is effected by a continuous addition of lime and soda, and the apparatus requires a daily cleansing. Howatson's industrial filters, having crushed silex, charcoal or polarite as filtering materials, are also used.

With respect to all of these rapid filters, we may say that what is gained in rapidity is lost in efficiency. It is true that the character of the water may be greatly improved; in fact, we may remove all the suspended matter, if the pores of the material are fine enough; it is true likewise that we may cause chemical changes which will improve the water, converting some of the objectionable minerals or gases, and some of the organic matter, into unobjectionable compounds; and finally, it is true that we can remove a very high percentage and occasionally all of the microbes which inhabit the impure water. But we cannot place entire confidence in rapid filtration for always turning out pure water.

We have already observed that rapid filters require frequent attention to keep them clean. If this attention be omitted, the water is worse than in its original state. The accumulation of organic matter in the filter and the equally great accumulation of bacteria, may then render the filter a positive danger by having been converted into a disease-breeding mass. This may occur after a few days of service.

We cannot, therefore, too urgently insist upon knowing the composition and construction of filters that we use, and upon giving them the attention which is absolutely necessary to guard us against the danger which can otherwise arise from them. No rapid filter will remain safe for many days without cleaning, and if much water is drawn from them, they must be cleaned almost daily in order that they may continue to furnish pure water.

We now come to the last division of my subject, viz.: that of *slow* filtration, by which we understand a percolation of water through the filtering material without completely filling its pores. This may be called the natural filtration of water, because in nature this same process trans-

forms the more or less polluted rain and surface water into a pure spring or ground water. It accomplishes the purification not only by removing the suspended and dissolved organic matter, which serves as food for bacteria, but also by removing these bacteria themselves, not by a process of straining, as sometimes takes place in rapid filtration, but, we may say, by a process of starvation.

In the earliest attempts at purification by slow filtration, the effort was merely to clarify the liquid; there was no endeavor to remove the dissolved and invisible suspended matter. Later it was found necessary to pay attention to these matters, and particularly to the removal of particles of an organic nature. Pasteur first proved that fermentation was caused not by decomposing organic matter, but by living organisms, and that living organisms were also the cause of many, and perhaps all, zymotic diseases. It was then discovered that filtration removed most of these organisms or bacteria. It is now known that a perfect filter may, under certain conditions, cause a complete destruction of the organic matter in the presence of these bacteria. It is not known in just what manner they effect this destruction, but that they do so in some way is proven by the fact that, when we destroy the bacteria themselves in the impure water, this passes through a filter merely strained and not deprived of its dissolved organic matter. We may destroy the bacteria, for instance, by mixing with the water some poison, such as chloroform. Again, we find that when the temperature is reduced to the freezing point, the water issues in an impure state. It has also been observed that in darkness the purification is not so efficient as in the light. All of this shows that the conditions conducive to organic life are necessary for the complete purification of water.

We must, therefore, provide conditions which will enable the bacteria to do their work as efficiently as possible. After they have done so and have deprived the water of all of their food, they will, of course, perish from starvation.

One of the important conditions for the life of the bacteria is the presence, in the water, of a certain quantity of oxygen, to be used in the conversion of the organic into

mineral compounds. It is, therefore, necessary to replenish the oxygen by aëration until the purification has been completed. This requirement explains the fact that a continuous filter in which the pores are completely filled with water, eventually prevents the bacteria from completing their work. A supply of the air necessary for their action can be furnished only by what is termed "intermittent" filtration.

Many filters have, however, proven effective for a while without this intermittency, this effectiveness being due to the formation, on top of the filter bed, of a film or skin, consisting of the retained organic matter, most of which is, in some cases, in a coagulated state. The bacteria are then kept out by a straining process similar to that which we mentioned as taking place to some extent by the precipitation method of removing organic matter and bacteria. But in time this layer of coagulated matter will obstruct the filter completely, and it requires to be periodically removed. Experience has shown that, immediately after cleaning, a large number of bacteria will pass through into the effluent water. After a while, again a fresh skin forms and the water becomes purer, because there is once more a fine strainer to keep the objectionable particles from passing through. A permanently effective filter, therefore, requires intermittency, by which the bacteria are destroyed through the more or less complete oxidation of the organic matter, caused by a liberal contact with air in the interstices of the material. In certain cases, in which the water naturally contains a sufficient quantity of oxygen, continuous filtration produces excellent results. The carbon is converted into carbonic acid and the nitrogen into nitric acid, which at once combines with the bases contained in the liquid or the soil, and forms harmless nitrates.

English, German and French scientists have made many investigations on this subject, and have reached some valuable conclusions; but it remained for the Massachusetts State Board of Health, through the investigations mainly of Messrs. Mills, Sedgwick, Drown, Hazen and Fuller, to investigate the subject systematically on a large scale and

to formulate its principles in a definite, tangible and practical manner. The results of the Massachusetts investigation have been published in the annual reports of the State Board of Health. They have also been summarized in several papers read before the International Engineering and Public Health Congress in Chicago last summer, by Messrs. Hiram F. Mills and George W. Fuller.*

From these we may quote as follows: "The circumstances that bring most clearly to mind the essential conditions of intermittent filtration are these: A bed of gravel stones, as large as robin's eggs, having an abundance of nitrifying organisms attached to each stone, has sewage poured over it for a short time; after the sewage has settled away, every stone it has reached is covered with a thin film of liquid in contact with air and enveloping the nitrifying organisms. Then nitrification takes place rapidly and with great completeness. A single hour will make a marked change in the character of the adhering liquid.

"After a few hours another charge of sewage distributed over the filter will mingle somewhat with the former adhering liquid and cause it to move downward. If this charge is too abundant, a part of it may flow too rapidly through the large interstices between the stones and reach the outlet drains without being completely nitrified. This condition limits the amount that can be purified by coarse materials. The air spaces are larger than necessary, and the area of surface is small. By decreasing the diameter of the stones to one-tenth of their present diameter, we may still have the same amount of air and water space and ten times the surface to which the water may adhere. In this case the air spaces between the films, though very much smaller than before, are sufficient to supply the oxygen necessary for nitrification if we allow sufficient time between applications for the sand to become drained. It is, however, evident that if we continue diminishing the diameter of the grains

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*"Purification of Sewage and of Water by Filtration." By Hiram F. Mills, A.M., C.E.; "Removal of Pathogenic Bacteria by Sand Filtration." By George W. Fuller.; Papers prepared for the International Engineering Congress of the Columbian Exposition. 1893.

of material, we shall reach a condition in which the films of water adhering to the grains will occupy the whole space; there is then no room for air, and nitrification cannot take place. Sand in a filter bed, that remains saturated after draining twenty-four hours, is of little value, and may be very objectionable."

Up to the present time the experiments of the State Board of Health indicate that the sand of even grain, that presents the conditions most favorable for the complete purification of sewage, has a diameter of grain of about 0·2 of a millimeter, or about 0·008 of an inch.

The quantity of sewage that may be permanently, though intermittently, applied to filters of such sand, is about 100,000 gallons per acre daily.

"The very complete purification here referred to produces an effluent chemically as good as many drinking waters, having in 100,000 parts about 0·0020 part of free ammonia, and about 0·0130 part of albuminoid ammonia, the former being but one-tenth of one per cent. and the latter but two per cent. of the amount in the sewage. Nearly all of the organic matter of the sewage is oxidized, forming, in the effluent, soluble nitrates to the extent of about 1·8 parts in 100,000. Bacteriologically, the results are even more remarkable, there remaining in the effluent less than 1 in 10,000 of the number applied in the sewage. The appearance of the effluent is that of a bright, clear spring water."

The surface of the filter should, in the intermissions between the applications, remain uncovered for a period much longer than that during which it is covered.

Polluted water supplies may be purified in a similar manner. As they, however, contain some free oxygen dissolved they do not require so much air in the sand as does sewage. Hence, much larger quantities, say, ten to twenty times as much, or between 1,000,000 and 2,000,000 gallons daily per acre, can be passed through the filter.

In this case, the accumulation of suspended matter is more rapid, and, in order to maintain the efficiency of the filter, the deposits should be removed at more frequent inter-

vals. It was found that 60,000,000 gallons of water, passing through one acre of the sand, as mentioned above, required the removal of one-eighth of an inch of sand and sediment. Therefore, when filtering 2,000,000 gallons daily, about one-eighth of an inch should be removed every thirty days.

"Most of the tests which the State Board of Health relies upon, as giving the efficiency of different filters in removing disease germs, have been made by applying to the filters water containing large numbers of the typhoid bacillus or of the more easily recognized *Bacillus prodigiosus*.

"These tests show that the best sands containing large numbers of these bacilli may have from 1,500,000 to 3,000,000 gallons of water filtered daily per acre, with the constant removal of more than 99½ per cent. of their number.

"In actual practice such results can only be obtained by constructing the filters with great care, so that the sand forms a homogeneous mass without stratification or channels with coarser grains, allowing a larger quantity of water to pass through the interstices. Mr. Mills has recently designed and built a filter at Lawrence, Mass., for the purification of the Merrimac River water which supplies the city, based upon the results obtained by the investigations of the State Board of Health. It is the first filter for water supplies that has been built in this country, where the principle of intermittency has been consistently and intelligently applied, and the results so far have amply rewarded the care taken in the construction, and confirmed the results obtained in the smaller experimental filters of the State Board of Health. It covers an area of two and one-half acres and has a capacity of 5,000,000 gallons daily.

"In summing up our present knowledge of the removal of pathogenic bacteria from drinking water, we may state that in addition to the experience of certain European cities, the Lawrence investigations, covering more than five years and including the bacterial examinations of more than 11,000 samples of water, indicate that it is entirely practicable to construct filters which will purify water economically, and remove more than ninety-nine per cent. of the bacteria in the unfiltered water."

SCIENCE IN THE FOUNDRY.

A Prospective and a Retrospective View.

BY ALEX. E. OUTERBRIDGE, JR.

In a paper upon progress in applied science, which appeared in February, 1882, in an educational magazine called the *Penn Monthly*, the writer, foreseeing the dawn of a new era in metallurgical science as applied to foundry practice, said: "The chemistry of iron is being more carefully studied. Manufacturers are beginning to realize that pig iron is not a simple substance, but is, in reality, an alloy, composed of a number of dissimilar elements; that its physical characteristics, such as strength, elasticity, etc., depend upon the percentages of these constituents, and that pure iron, like pure gold, is always the same thing physically and chemically, no matter from what source it may be obtained.

"We believe that the time is coming when pig iron will be sold on its chemical analysis, instead of on the crude methods of grading at present in vogue; and further, that, as the naturalist can accurately tell the genus of an animal from an examination of a single bone, so the analyst will tell the physical qualities of a mass of iron from an analysis of its component parts."

Events have proved that this statement was at least partially prophetic.

Not many years ago, a chemist in a foundry, would have been generally regarded as a curiosity, and the idea of controlling foundry mixtures by chemical analysis, would have been considered an expensive refinement.

It is true that, in a few special cases, scientific methods had been tentatively tried years ago, for instance, in the manufacture of chilled cast-iron car wheels, where a product of peculiar quality and uniform character was absolutely requisite, and where also changed conditions of business necessitated new methods.

The "ideal" iron for car wheels is a metal having an extremely dark, "open-grained," or coarse fracture, in the body or "plate" of the wheel, and a pure white, fine-grained adamantine structure, on the "tread," extending to a depth of about half an inch beneath the surface, and merging gradually into the soft gray iron backing.

According to the old nomenclature, such metal may be said to have a gray iron fracture, equivalent to "No. IX," with an artificial crystallization, or chilling quality, equal to "No. 6," or white iron. Formerly, this ideal quality of metal for car-wheels was actually produced in this country, and there is no doubt that this essentially American industry was indebted to that fact for its origin contemporaneously with the birth of the railway system half a century ago.

The gradual dismantling of old-time cold blast charcoal iron furnaces, and the increasing difficulty of obtaining pig iron adapted to the manufacture of chilled wheels, compelled the makers of this product to investigate chemically the elements composing such metal, with the view of ascertaining definitely the cause of the special property of "chilling," which, for many years, was peculiar to pig iron made with charcoal fuel by a cold blast, and could not be successfully produced by any other method of manufacture. The entering wedge in this study was introduced about the year 1879, by Dr. Dudley, chemist to the Pennsylvania Railroad; and, shortly after this, the writer was called upon to take up a similar work for a large establishment in Philadelphia, engaged since 1847, in the manufacture of chilled wheels.

Dr. Dudley generously imparted the facts which he had gathered in the midst of many other important lines of investigation, and the writer took up these threads and found interesting occupation, extending over a period of several years, in weaving them together.

Some of the practical results of this investigation were embodied in a paper entitled the "Genesis of a Car Wheel," read before the Chemical Section of the Franklin Institute, in 1883, and later, in the more popular form of a lecture at

the same institution in 1888, on "Pig Iron: Including the Relation between its Physical Properties and its Chemical Constituents."*

It is admitted that chemical investigation has not only saved the car wheel industry from extinction, but also that it has enabled the manufacturer to turn out product to-day, which is subject to far more severe scrutiny before passing into service, and to vastly greater shocks and strains in ordinary use than heretofore, and at a minimum price. Indeed, it may be said in passing, that not the least wonderful feature of this special business is the price at which chilled cast-iron car wheels of good quality are now sold.

Within a very few years the subject of "Chemistry in the Foundry" has run riot in the discussions of the foundrymen's associations and in the journals devoted to iron interests. A vast amount of "green fruit" has been put upon the market, much of which has already withered before ripening; but this is not an unusual experience, and in taking a broad view of the subject, one can observe that considerable progress has been made.

Scientific system is gradually superseding rule-of-thumb, or empirical, methods, in progressive foundries, and much of the old-time superstition, born of ignorance, is being eradicated. This is true, not only in regard to the metallurgy of pig iron for castings, but also in regard to methods of moulding and other cognate branches of the founder's art. The influence of this newly-awakened interest is extending with results that are apparent in widely divergent directions. Pig iron is no longer valued solely by its appearance when fractured, but by its chemical constitution. The manufacturer of machinery is enabled to obtain castings from such foundries which are more certainly adapted to the special work for which they are designed, and he is also enabled to guarantee their quality, in regard to strength, etc.

The technical colleges are being equipped with improved testing machines of large capacity and marvellous accuracy,

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* *Vide*, this *Journal*, [**125**,] 223.

and the number of students devoting themselves to the metallurgy and chemistry of pig iron is increasing.

From these observations it may be inferred that, although the field for cast iron has been invaded to a great extent by cast steel, the producers of iron castings have been spurred on to improve their product, and thus to keep in line with the progress of the age, and to show that in spite of this formidable competition the field is still open for their occupation.

NOTES AND COMMENTS.*

THE SHIP CANAL THROUGH THE LAKES.

The daily journals contain the announcement that a bill has been introduced in the Senate authorizing the President to appoint three persons to confer with any similar committee appointed by Great Britain or Canada, and to report as to the feasibility of a canal for ocean vessels between the Atlantic and the Lakes; where it can most conveniently be located; the probable cost, with estimates in detail; and, if any part of the canal should be built in Canada, what arrangements are necessary to preserve it for use to the people of this country. All the necessary facts relating to the construction and use of such deep-water channel are also to be reported on, and it is proposed to appropriate $10,000, or so much thereof as may be necessary, for actual travelling and other necessary expenses, the members of the commission to serve without pay.

In view of the fact referred to in my annual report to the Institute, that the Dominion of Canada has already expended the enormous sum of $67,000,000 for the construction, on Canadian territory, of a continuous chain of waterways connecting the Great Lakes with the Ocean, and navigable by ocean-going vessels, it is exceedingly improbable that either Canada or the mother country would wish to confer upon a matter that is already practically *un fait accompli;* and especially since the manifest purpose of this Canadian enterprise, as I had occasion to point out in my previous communication, is to render the Dominion independent of the United States in the possession of this important avenue to the Ocean.

PRESENT CONDITION OF NIAGARA FALLS POWER PLANT.

Prof. George Forbes, in a recent communication to the London *Times*, describes the present condition of the power plant at Niagara Falls as follows: "Nearly three years ago you published a letter from this place in which I gave some account of how the dreams of the engineer were in the act of being realized, and without injury to the natural beauties of the spot. Three years have passed, my work is ended, and it seems natural to continue

* From the report of the Secretary to the stated meeting of the Institute, held February 20, 1895.

the narrative and tell what these three years have brought forth. I am perched on top of a small Eiffel tower, lately erected, and, casting my eyes up the river, over the housetops and beyond the town, I see a new world created. There is a wide canal leading water into that gigantic power house, where three turbines are set up to drive three dynamos of 5,000 horse-power each. There is the bridge to carry cables across to the transformer house. Inside the power house the water is carried down by pipes 7½ feet diameter into the turbines, whence it passes through a 7,000 feet tunnel under the town, emerging below the Falls, and capable of developing 100,000 horse-power. Far as the eye can reach extend the company's lands, with here and there a huge factory either now using the water-power, or waiting for the electric supply. One of them uses 3,300 horse-power, another 300, a third one 1,500, and that unfinished mill requires 1,000. You can see, far away, the model village for workingmen and improved sewage works with drainage, pumps for water supply, electric light and well-paved streets. There, again, is the dock, where ships from all parts of the Great Lakes can unload, and there a huge expanse of reclaimed land; while the whole is swept by the company's railway, seven miles long, connecting every factory with the great trunk lines. The power is transmitted by electricity, and the first work is to produce aluminum with 1,500 horse-power. New types of machines have been devised for this work, as also for every other purpose. All criticism as to cost of electric works has been swept away by the results achieved, and the efficiency of each type of machine is greater than has been attained before. All the machinery for the first working has been made and tested in the shops, and the last parts are now being set up. The plans for carrying the power to Buffalo, eighteen miles distant, are complete. In a month or two factories will be in full operation; in a year Buffalo will be supplied; in two years the same company will be working the Canadian side of the Falls, and in ten years (shall we say?) the whole of the 100,000 horse-power which can be supplied by the existing hydraulic works will be giving power to smokeless manufacturing towns. The period of planning the transmission scheme, of designing the greatest dynamos in the world, and of construction of the first plant now closes. The financial period commences with the new year. The earning of dividends and the ordering of duplicate machinery is the future work of the company. In conclusion, it is difficult for me to say who were the boldest—the capitalists who embarked on the scheme before any plans were matured, or the manufacturers who moved their factories to this field before a single result had been achieved. The action of both was typically American, but their confidence was not misplaced. Their success is now assured."

I take from the *Electrical Engineer* the following account of the condition of the electrical part of the plant:

The turbines built by the I. P. Morris Company are in position and all the galleries, the ladders, the elevators and the electric lights have been placed in the wheel pit.

Men are now at work putting in the turbine oiling apparatus, with the tanks, filters, pipes and pumps. A novel way of operating the force pumps

which take the oil up through the pipes to the upper tank has been developed. All the water which leaks into the wheel pit is collected by a ring around the pit into a reservoir about a third of the way down the pit, and is used to run the pumps. A pressure of ninety pounds to the inch is secured by this surplus water.

The main-switch-board room in the power house is also well under way. It is to be constructed of white enamelled brick, and when finished will be 58 feet long, 13 feet wide and 8 feet high. The front will be composed of ten heavy plate-glass windows, while the top of the inclosure will be an observation platform, inclosed in a brass railing, for visitors. This room will contain some of the heaviest switches thus far constructed, and will be one of the most interesting features of the power plant. The transformer building, which stands over the mouth of the electric subway, is also well up to the roof. It is of the same style of architecture as the main power building, massively constructed.

The alternating current dynamos, built by the Westinghouse Company, are thus described:

To a circular foundation is bolted a vertical cast-iron cylinder, provided with a flange on which the stationary armature rests. The inner part of the cylinder is bored to the shape of an inverted cone, and serves as a bearing for another conical piece of cast iron supporting the shaft bearings. The armature core is made of thin oxidized iron plates, held together by eight nickel steel bolts. In the outer edge of the plates are 187 rectangular holes to receive the armature winding.

The outer rotating field magnet consists of a wrought-steel ring, to which are bolted the twelve inwardly-projecting massive cast-iron pole pieces. The ring constituting the field magnet is supported by a six-armed cast-steel spider keyed to a vertical axis. The field magnets act also as a fly-wheel. The shaft rests on two bearings supported by four arms projecting from the inner adjustable cast-iron cylinder. The bushings of the bearings are made of bronze provided with zig-zag grooves, in which oil constantly circulates. On the outer side of the bushing there are also grooves into which cold water may be pumped if required.

The armature conductors are rectangular copper bars 32 x 8 mm. and each of the 187 holes of the armature contains two of these bars, surrounded with mica. The upper and under sides of the armature are connected by means of V-shaped copper bars, riveted to the ends of the bars, which project out behind the ends of the armature. The connections are made so as to give two independent circuits, a pair of cables connecting each circuit with the switch-board. The magnet winding is also composed of bent copper bars, air insulated, inclosed in brass boxes, two of which are fastened to each pole piece. Continuous current for exciting the field magnets is obtained from a rotary transformer.

The current is conducted to the field coils by means of a pair of brushes and two copper rings fixed to the top of the shaft of the generator. At a speed of 250 revolutions per minute the machine produces two alternating currents, differing in phase 90° from each other, each of 775 ampères and

2,250 volts pressure. The alternations are fifty per second. The height from base of bed plate to top of machine is nearly 13½ feet.

A SUBSTITUTE WANTED FOR WOOD IN THE CONSTRUCTION OF WARSHIPS.

A board of experts, of which Commissioner Bradford is senior member, was lately convened by direction of the Secretary of the Navy to consider the subject of dispensing with wood in the construction of the naval ships now building, and also for the purpose of finding some suitable substitute for wood in places where it is impracticable to use metal. Since the naval action fought off the mouth of the Yalu River, between the Chinese and Japanese fleets, during which several ships were disabled and thrown out of action by serious fires on board, the matter has received much attention at home and abroad. The German Admiralty has convened a board to find a suitable substitute for wood; in the meantime, the use of wood on other ships has ceased altogether, even the furniture being made of iron, and cork being used where a non-conductor is absolutely necessary.

The English, it is stated, have not yet come to any decision in the premises, but are casting about for some substitute for wood. The French have for a long time used a minimum of wood, and, in all foreign ships, less wood has probably been used than in those of our service.

The problem is not an easy one. While there is no doubt that the abolition of all combustible material will add to the fighting efficiency of ships of war, there would be serious risk that they would be rendered uninhabitable. Owing to the good conducting properties of iron and steel the living quarters, if not sheathed with some non-conductor, become intensely cold in winter and very hot in summer. Where heat is applied, owing to the difference of temperature on the opposite sides of the metal plating, much condensation of moisture occurs. These conditions are active agencies in the causation of rheumatism and pulmonary diseases. Clothing kept in metal drawers and lockers becomes ruined from moisture, and the drawers must be lined with something in the nature of wood or thick felt. The board has decided that a substitute for wood should have the following properties:

It should be light, or no heavier than wood, non-conducting, non-combustible, and, when struck by shot, should not fly into splinters. When used for bulkheads, berths, shelves, lockers, etc., it should be strong and capable of being worked into shapes with tools. For linings on metal, no great strength is required. Several manufacturers of metal goods and furniture have offered to make samples for the board to pass upon. Chemists and others are engaged in experiments with the object of producing an artificial wood. Manufacturers of fire-proof paints and liquids have given some very successful exhibitions of their wares; but surface protection of wood, however, is insufficient and of no avail when the wood becomes splintered by a hailstorm of small projectiles. Furthermore, wood has the very objectionable property of splintering from the effect of shot and the fact is well known

that, in wooden ships, frequently, as many persons are wounded by splinters as by shot.

A solution of the problem of finding a substitute for wood, seems, in the opinion of the board, to lie in the following direction:

Take something in the nature of cheap wood or vegetable fibre and fine sawdust; treat them chemically with some insoluble fire-proof substance, not too heavy; then press and roll into boards, more or less dense, according to the use for which the material is desired. Such a material will be non-inflammable all through, will not splinter, will not be heavy and will be a non-conductor. Possibly this artificial board can be strengthened by enclosing within it a tough, fine, wire netting. If sawdust, or other fine cellulose material, after being rendered non-inflammable, can, by mixing with other materials not too heavy—or, if heavy, in small quantities—be applied to metal in a plastic state, so as to harden into a compact mass impervious to water, then it will be of great value. In other words, if a light, non-conducting, non-inflammable, insoluble cement can be discovered, it will be of great use in ship construction.

THE COMMERCIAL SYNTHESIS OF ILLUMINATING HYDROCARBONS.

In the report which I had the honor to present at the December meeting of the Institute, I made reference to the interesting announcement by Mr. T. L. Willson, of a cheap and practical method of producing calcium carbide, by heating an intimate mixture of lime and carbon in the electric furnace, and explained the method of producing acetylene from this compound by bringing it in contact with water. An abstract was published in the *Journal* for January, 1895, of a paper by Dr. Francis Wyatt, giving details of the method of manufacture, and indicating in a general way the probable future utility of this observation.

The following additional contribution to the subject, which is abstracted from a paper lately read before the London *Society of Arts*, by Prof. Vivian B. Lewes, throws considerable light upon it, and will be read with interest:

"The direct combination of carbon and hydrogen in the electric arc is a true case of synthesis, and if we could form acetylene in this way in sufficiently large quantities, it would be perfectly easy to build up from the acetylene the whole of the other hydrocarbons which can be used for illuminating purposes. For instance, if acetylene be passed through a tube heated to just visible redness, it is rapidly and readily converted into benzol; at a higher temperature, naphthalene is produced; whilst, by the action of nascent hydrogen on acetylene, ethylene and ethane can be built up. From the benzol we readily derive aniline, and the whole of that magnificent series of coloring matters which have gladdened the heart of the fair portion of the community during the past five-and-twenty years; whilst the ethylene produced from acetylene, can readily be converted into ethyl alcohol, by consecutively treating it with sulphuric acid and water. From the alcohol,

again, an enormous number of other organic substances can be produced, so that acetylene can, without exaggeration, be looked upon as one of the great keystones of the organic edifice, and, given a cheap and easy method of preparing this substance, it is hardly possible to foresee the results which will be ultimately produced.

"In 1836, it was found that when making potassium, by distillation from potassic carbonate and carbon, small quantities of a by-product, consisting of a compound of potassium and carbon, was produced, and that this was decomposed by water with liberation of acetylene; whilst Wöhler, by fusing an alloy of zinc and calcium with carbon, made calcic carbide, and used it as a source from which to obtain acetylene by the action of water.

"Nothing more was done until 1892, when Macquenne prepared barium carbide, by heating, at a high temperature, a mixture of barium carbonate, powdered magnesium, and charcoal, the resulting mass evolving acetylene, when treated with water; whilst, still later, Travers made calcic carbide, by heating together calcic chloride, carbon and sodium. None of these processes, however, gave any commercial promise, as the costly nature of the potassium, sodium, magnesium, or calcium-zinc alloy which had to be used, made the acetylene produced from the carbide too expensive.

"Whilst working with an electric furnace, and endeavoring by its aid to form an alloy of calcium from some of its compounds, Mr. T. L. Willson noticed that a mixture, containing lime and powdered anthracite, under the influence of the temperature of the arc, fused down to a heavy semi-metallic mass, which having been examined, and found not to be the substance sought, was thrown into a bucket containing water, with the result that violent effervescence of the water marked the rapid evolution of a gas, the overwhelming odor of which enforced attention to its presence, and which, on the application of a light, burnt with a smoky, but luminous flame.

"Investigation into the cause of this phenomenon soon showed that in a properly constructed electric furnace, finely powdered chalk or lime, mixed with powdered carbon in any form, whether it were charcoal, anthracite, coke, coal or graphite, can be fused with the formation of a compound known as calcic carbide, containing 40 parts by weight of the element calcium, the basis of lime, and 24 parts by weight of carbon, and that, on the addition to this of water, a double decomposition takes place, the oxygen of the water combining with the calcium of the calcic carbide to form calcic oxide or lime, whilst the hydrogen unites with the carbon of the calcic carbide to form acetylene, the cost of the gas so produced bringing it not only within the range of commercial possibilities for use *per se*, but also the building up from it of a host of other compounds, whilst the production of the calcic carbide from chalk and from any form of carbon, renders us practically independent of coal and oil, and places in our hands the prime factor by which nature in all probability produces those great underground storehouses of liquid fuel upon which the world is so largely drawing to-day.

"Calcic carbide is a dark gray substance, having a specific gravity of 2·262, and, when pure, a pound of it will yield on decomposition 5·3 cubic feet of acetylene. Unless, however, it is quite fresh, or means have been taken to

carefully protect it from air, the outer surface gets slightly acted upon by atmospheric moisture, so that in practice the yield would not exceed 5 cubic feet. The density and hardness of the mass, however, to a great extent protect it from atmospheric action, so that in lumps it does not deteriorate as fast as would be expected, but in the powdered condition it is rapidly acted upon.

"The acetylene made from it, when analyzed by absorption with bromine, the analysis being also checked by determining the amount present by precipitation of silver acetylide, gives 98 per cent. of acetylene and 2 per cent. of air, and traces of sulphuretted hydrogen; the presence of this impurity being due to traces of sulphate of lime—gypsum—in the chalk used for making it, and to pyrites in the coal employed.

"Acetylene is a clear, colorless gas with an intensely penetrating odor which somewhat resembles garlic, its strong smell being a very great safeguard in its use, as the smallest leakage would be at once detected; indeed, so pungent is this odor, that it would be impossible, without recognizing the fact, to go into a room which contained any dangerous quantity of the gas.

"This is an important point to remember, as the researches of Bistrow and Liebreich show that the gas is poisonous, combining with the hæmoglobin of the blood to form a compound similar to that produced by carbon monoxide; whilst the great danger of the latter gas is, that, having no smell, its presence is not detected until symptoms of poisoning begin to show themselves. With acetylene no fear need be apprehended of danger from this cause.

"Acetylene is soluble in water and in most other liquids, and, at ordinary temperature and pressure—60° F. and 30″ of mercury—10 volumes of water will absorb 11 volumes of the gas; but, as soon as the gas is dissolved, the water being saturated takes up no more. Water already saturated with coal gas does not take up acetylene quite so readily, whilst the gas is practically insoluble in saturated brine—100 volumes of a saturated salt solution dissolving only 5 volumes of the gas. The gas is far more soluble in alcohol, which, at normal temperature and pressure, takes up six times its own volume of the acetylene; whilst 10 volumes of paraffin, under the same conditions, will absorb 26 volumes of the gas. It is a heavy gas, having a specific gravity of 0·91.

"When a light is applied to acetylene, it burns with a luminous and intensely smoky flame, and, when a mixture of one volume of acetylene with one volume of air is ignited, in a cylinder, a dull red flame runs down the cylinder, leaving behind a mass of soot, and throwing out a dense black smoke. When acetylene is mixed with 1·25 times its own volume of air, the mixture begins to be slightly explosive, the explosive violence increasing until it reaches a maximum with about twelve times its volume of air, and gradually decreasing in violence, until, with a mixture of one volume of acetylene to twenty of air, it ceases to be explosive.

"The gas can be condensed to a liquid by pressure. Andsell found that it liquefied at a pressure of 21·5 atmospheres, at a temperature of 0° C.; whilst Cailletet found that, at 1° C., it required a pressure of 48 atmospheres; the first-named pressure being probably about the correct one. The liquid

so produced is mobile, and highly refractive, and, when sprayed into air, the conversion of the liquid into the gaseous condition absorbs so much heat that some of the escaping liquid is converted into a snow-like solid, which catches fire on applying a light to it, and burns until the solid is all converted into gas and is consumed.

"In my researches upon the luminosity of flame, I have shown that all the hydrocarbons present in coal gas and other luminous flames, are converted, by the baking action taking place in the inner non-luminous zone of the flame, into acetylene, before any luminosity is produced, and that it is the acetylene, which, by its rapid decomposition at 1,200° C., provides the luminous flame with these carbon particles, which, being heated to incandescence by various causes, endow the flame with the power of emitting light. The acetylene, being in this way proved to be the cause of luminosity, one would expect that in this gas we have the most powerful of the gaseous hydrocarbon illuminants, and experiment at once shows that this is the case.

"Owing to its intense richness, it can only be consumed in small flat-flame burners, but under these conditions emits a light greater than that given by any other known gas, its illuminating value calculated to a consumption of 5 cubic feet an hour being no less than 240 candles.

ILLUMINATING POWER OF HYDROCARBONS FOR A CONSUMPTION OF 5 CUBIC FEET OF GAS.

	Candles.
Methane	5·2
Ethane	35·7
Propane	56·7
Ethylene	70·0
Butylene	123·0
Acetylene	240·0

"It is stated that the carbide can be made at about £4 a ton; and if this be so, it should have a great future, as a ton will yield 11,000 cubic feet of the gas. The lime left as a by-product would be worth 10*s.* a ton, and the gas would cost at this rate 6*s.* 4½*d.* per 1,000 cubic feet, and, in illuminating value, would be equal to London coal gas at 6*d.* a thousand. Its easy production would make it available for illuminating purposes in country houses, whilst its high illuminating value should make it useful for enriching poor coal gas."

A NEW ELEMENT IN THE NITROGEN GROUP.

Mr. A. E. Tuttle communicates to London *Nature*, the following concise abstract of an important communication made by Dr. Beyer to the *Société Chimique*, describing a new element which he has discovered in the residual liquors derived from the older process for the extraction of aluminum from red beauxite. The liquors in question consist chiefly of sulphate and carbonate of sodium; but there are also present considerable quantities of chromic and vanadic acids; and smaller quantities of molybdic, silicic, arsenic, phosphoric, and tungstic acids; together with alumina, magnesia and lime, and an acid of the new element. In order to isolate the latter, the vanadium and chromium are first removed, the former as the difficultly-soluble ammonium van-

adate, and the latter as hydrated sesquioxide. The filtered liquid is then saturated with sulphuretted hydrogen, and the sulphides, all of which are soluble in the alkaline liquid, are precipitated by hydrochloric acid. This precipitate exhibits a deep brown color, due to the new element. When dried, it presents a brown, earthy appearance, and burns readily with evolution of sulphur dioxide and formation of a bright brown powder. Concentrated nitric acid instantly causes ignition, and formation of a deep brown solution, from which a small quantity of a yellow precipitate of a compound of molybdic and arsenic acids is deposited. The brown liquid contains no tin, antimony or tellurium, but still retains traces of vanadium, molybdenum and selenium These elements are best removed by calcination of the sulphides immediately after their precipitation with hydrochloric acid; when selenium is volatilized, treatment of the residue with ammonia and ammonium nitrate, which precipitate the last traces of vanadium as ammonium vanadate; and concentration of the filtered liquid, which causes deposition of ammonium molybdate. During the concentration two distinct crops of different crystals are obtained, the first, and most sparingly soluble, being cubic crystals of an olive-brown color; and the second, the much more soluble ammonium molybdate. The olive-brown cubic crystals contain the new element, together with a little molybdenum. The latter is readily removed by dissolving the crystals in dilute hydrochloric acid, and passing a current of sulphuretted hydrogen through the liquid heated to about 70°. The new element is not precipitated by sulphuretted hydrogen, in an acid solution. The filtered liquid is then allowed to evaporate in the air. At first it is bluish-violet in color, and contains the new element in a low state of oxidation; subsequently it becomes oxidized, and the color changes to lemon-yellow. The oxide in the latter stage possesses marked acid proclivities, and probably corresponds to the formula R_2O_5. The acid itself is soluble in water, from which it is deposited in yellow crystals, which, at a red heat, fuse to a brownish yellow mass. Ammonia transforms the acid into a crystalline powder of olive color, presumably an ammonium salt, which readily dissolves in hot water and on cooling crystallizes from the solution in cubes. The solution is olive-green, and is precipitated by strong ammonia. The solution of the acid, after reduction with sulphuretted hydrogen in presence of hydrochloric acid, yields with ammonia, a voluminous deep violet-brown precipitate, which rapidly becomes crystalline. The precipitation is not complete, hence the supernatant liquid is colored violet. Caustic soda and sodium carbonate, likewise, incompletely precipitate it, owing to solubility of the precipitate in excess of the reagent with formation of a soluble salt. Chlorides of barium and calcium produce grayish-violet precipitates of the salts of those metals.

An especially interesting reaction is that with ammonium sulphide, with which, the highly oxidized yellow solution of the acid, yields a deep cherry-red coloration, due to a sulpho-salt. Acids precipitate from this solution a sulphide of the color of iron rust. Silver nitrate produces a green precipitate of the silver salt, soluble both in nitric acid and in ammonia, and if the solution in the latter solvent is effected at a moderately elevated temperature the, silver salt is deposited in crystals upon cooling. Magnesia mixture gives,

after standing a few minutes, a green precipitate analogous to ammonium-magnesium phosphate, and, owing to the slowness of the precipitation, the latter occurs in the form of relatively large crystals; moreover, the precipitation is complete after a short time, for the liquid, which at first is green, becomes colorless. A yellow precipitate is likewise afforded with a nitric acid solution of ammonium molybdate, as in the case of phosphoric acid. The chlorides of the new element appear to be volatile, for very considerable loss occurs on attempting to remove by ignition any admixed ammonium salts, for instance, from the solution obtained after removal of the vanadium as previously described. A yellow sublimate is produced having all the characters of a chloride of the new element, and which is readily soluble in water.

A sufficient quantity of the new element, in the form of any of its compounds, has not yet been accumulated to enable exact quantitative analyses to be carried out, but Dr. Bayer hopes shortly to have obtained the amount requisite for this purpose and for the determination of the atomic weight of the element. There appears to be little room for doubt that it will prove to be one of the missing elements predicted by Professor Mendeléeff in the nitrogen-phosphorus group. It exhibits characteristic spectroscopic lines in the green, blue and violet.

ARGON: A NEW CONSTITUENT OF THE ATMOSPHERE.

In a paper bearing this title, recently read before the Royal Society, Lord Rayleigh and Professor Ramsay described the results of their researches into the nature and properties of argon, the new constituent of the atmosphere.

The following abstract of this communication is taken from the *Engineering and Mining Journal:*

The separation of the unknown constituent was effected, as stated at the meeting of the British Association, by two different methods—absorption of nitrogen by red-hot magnesium, and a repetition of the experiment in which Cavendish removed the nitrogen by electric sparking in the presence of excess of oxygen and an alkali. An estimate was founded upon the data respecting the volume present in air, on the assumption that the densities of atmospheric and chemical nitrogen differ only on account of the presence of argon in the former, and that nothing but nitrogen is oxidized during the treatment with oxygen. According to this mode of calculation the density is 20·6. Calculation from the weight of a mixture of argon with oxygen gives, however, a density of 19·7. The most trustworthy results of a number of determinations of the density of argon prepared by means of magnesium, give the figure 19·9, which is the one practically accepted by the authors. By considerations drawn from the ratio of specific heats, the authors are led to regard argon as a monatomic gas, like mercury, and its atomic weight is therefore not twenty, but forty. Many attempts have been made to induce it to combine, but they have all as yet proved abortive. Argon does not combine with oxygen, in presence of alkali, under the influence of the electric discharge; nor with hydrogen, in presence of acid or alkali, when sparked; nor

with chlorine, dry or moist, when sparked; nor with phosphorus at a bright red heat; nor with sulphur at bright redness. Tellurium may be distilled in a current of the gas; so may sodium and potassium, their metallic lustre remaining unchanged. It is not absorbed when passed over fused red-hot caustic soda, or soda-lime heated to bright redness; it passes unaffected over fused and bright red-hot potassium nitrate, and red-hot sodium peroxide does not combine with it. Persulphides of sodium and calcium are also without action at a red heat. Platinum black does not absorb it, nor does platinum sponge, and wet ozidizing and chlorinating agents, such as nitro-hydrochloric acid, bromine water, bromine and alkali, and hydrochloric acid and potassium permanganate, are entirely without action. Experiments with fluorine are in contemplation, but the difficulty is great. An attempt will be made to produce a carbon arc in argon. Mixtures of sodium and silica, and of sodium and boracic anhydride, are also without action; hence it appears to resist attack by nascent silicon and by nascent boron. As to its physical properties, we have a little more information. Its solubility in water is relatively high, being two and a half times that of nitrogen. Its spectroscopic examination has been conducted by Mr. Crookes, who contributed a supplementary paper dealing with that portion of the subject. It has two distinct spectra, as has nitrogen itself. But while the nitrogen spectra are of different characters, one being a line and the other a band spectrum, the two spectra of argon are of the same type. The red lines are described as specially characteristic; there is a bright, yellow line, a group of five in the green, and five strong violet lines, of which the fourth is the most brilliant, and has a wave length of 420. The spectrum is identical, whether the substance be separated by magnesium, or by sparking. According to Professor Olzewski, of Cracow, the critical point of the new gas is 121°; the critical pressure, 50·6 atmospheres; the boiling point-187°; the melting point-189·6°; and the density of the liquid, 1·5.

BOOK NOTICES.

Popular Lectures and Addresses.—By Sir William Thomson (Baron Kelvin). Vol. II. Geology and General Physics. 8vo. Pp. 599. London and New York: Macmillan & Co. 1894.

The present volume of Lord Kelvin's popular lectures and addresses completes the series of three volumes. The theories discussed are well defined in the title of the volume, and several of them have given rise to animated discussion. The distinguished author, who is acknowledged as the leader of thought in the domain of physical science, has advanced views regarding "geological time" and "geological dynamics," which happen to differ substantially from those entertained by the geologists, and which, consequently, have been sharply criticised. The subjects considered in these lectures and addresses are treated in a style fully adapted to the comprehension of the intelligent reader, and, it need scarcely be added, will amply repay careful reading and study. W.

Electrical Papers.—By Oliver Heaviside (2 vols). Cloth. 8vo. Pp. 560-587. New York and London: Macmillan & Co. 1894. Price, $7.

These volumes constitute the collected papers of Mr. Heaviside, who is well known to many readers of the *Journal* for his valuable work as an elucidator of the modern theory of electro-magnetism.

The present edition of the author's works embraces, in addition to his various contributions to this subject, many papers on miscellaneous topics published during the past twenty years. The treatment is mathematical. W.

Electric Waves; being researches on the propagation of electric action with finite velocity through space. By Dr. Hemrich Hertz. London and New York: Macmillan & Co. Pp. xv + 278. Price, $2.50.

The importance to science of this comprehensive review of the theory of electric action cannot be too highly esteemed. It includes within its fourteen chapters, originally contributed to *Wiedemann's Annalen*, and now gathered by Prof. D. E. Jones, B.Sc., into a single volume, the record of scientific discovery, from the time of Newton and Bernoulli down to and including the work of the author himself, which is acknowledged by his contemporaries to be epoch-making. W.

Electricity One Hundred Years Ago and To-Day. With copious notes and extracts. By Edwin J. Houston, Ph.D. (Princeton). New York: The W. J. Johnston Company, Limited, 253 Broadway. Pp. 199. Illustrated. Price, $1.

In tracing the history of electrical science from its infancy to the present day, the author of this work has, wherever possible, consulted original sources of information, and he was fortunate to have at his disposal for this purpose the excellent library of the Franklin Institute, which contains, perhaps, the most complete collection of scientific publications of the last century to be found in this country.

As a result of these researches, several revisions of the dates of discovery of important principles in electrical science were found to be necessary. For example, it was found that Sir Humphrey Davy was anticipated in the discovery of the electric arc by many others, and, in fact, did not claim to have been the first to discover the brilliant effects of the arc. Proper credit is given to Gilbert for his inductive methods, and, in an appendix, several writers are quoted to show that Bacon has been honored above his merit in this respect.

While, as the author states, the compass of the book does not permit of any other than a general treatment of the subject, yet numerous references are given in foot-notes, which, also, in many cases, quote the words in which a discovery was first announced to the world, or give more specific information in regard to the subjects mentioned in the main portion of the book. This feature will be found of interest and value, for often a clearer idea may be obtained from the words of a discoverer of a phenomena or principle than is possible when they are presented at second-hand.

The work is not a mere catalogue of subjects and dates, nor is it couched in

technical language that is intelligible only to a few. On the contrary, one of its most admirable features is the agreeable style in which the work is written, its philosophical discussion as to the cause and effect of various discoveries, and its personal references to great names in electrical science. Much information as to electrical phenomena may also be obtained from the book, as the author is not satisfied to merely give the history of a discovery, but also adds a concise and clear explanation of its nature and scope. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, February 20, 1895*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 20, 1895.

Mr. JOS. M. WILSON, President, in the chair.

Present, thirty-nine members and ten visitors.

Additions to membership since last report, seven.

Mr. Henry R. Heyl was elected to fill the vacancy in the office of Vice-President, and Mr. Charles A. Hexamer to fill the vacancy in the Committee on Science and the Arts.

The amendments relating to the organization and government of the Sections, proposed by the Committee on Sectional Arrangements and recommended for adoption by the Board of Managers, were adopted by unanimous vote.

The Secretary presented and read a communication from the *Verein Deutscher Ingenieure*, of Berlin, setting forth the advantages to be attained by the adoption of a uniform system of screw-threads by all civilized nations, and asking whether the Franklin Institute would be disposed to co-operate in an international movement looking to the unification of screw-thread standards.

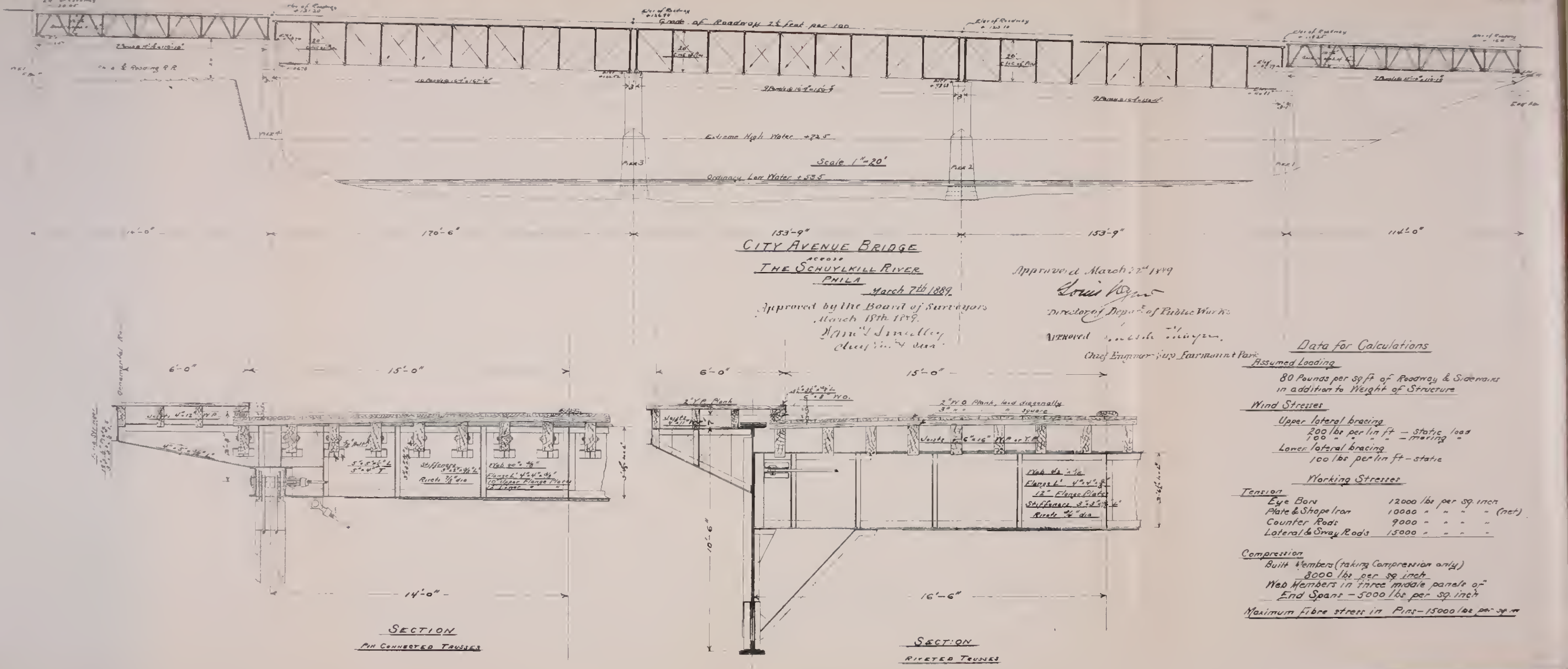
The meeting voted to authorize the President to appoint a committee to consider the expediency of such co-operation on the part of the Franklin Institute, and to report at the next stated meeting.

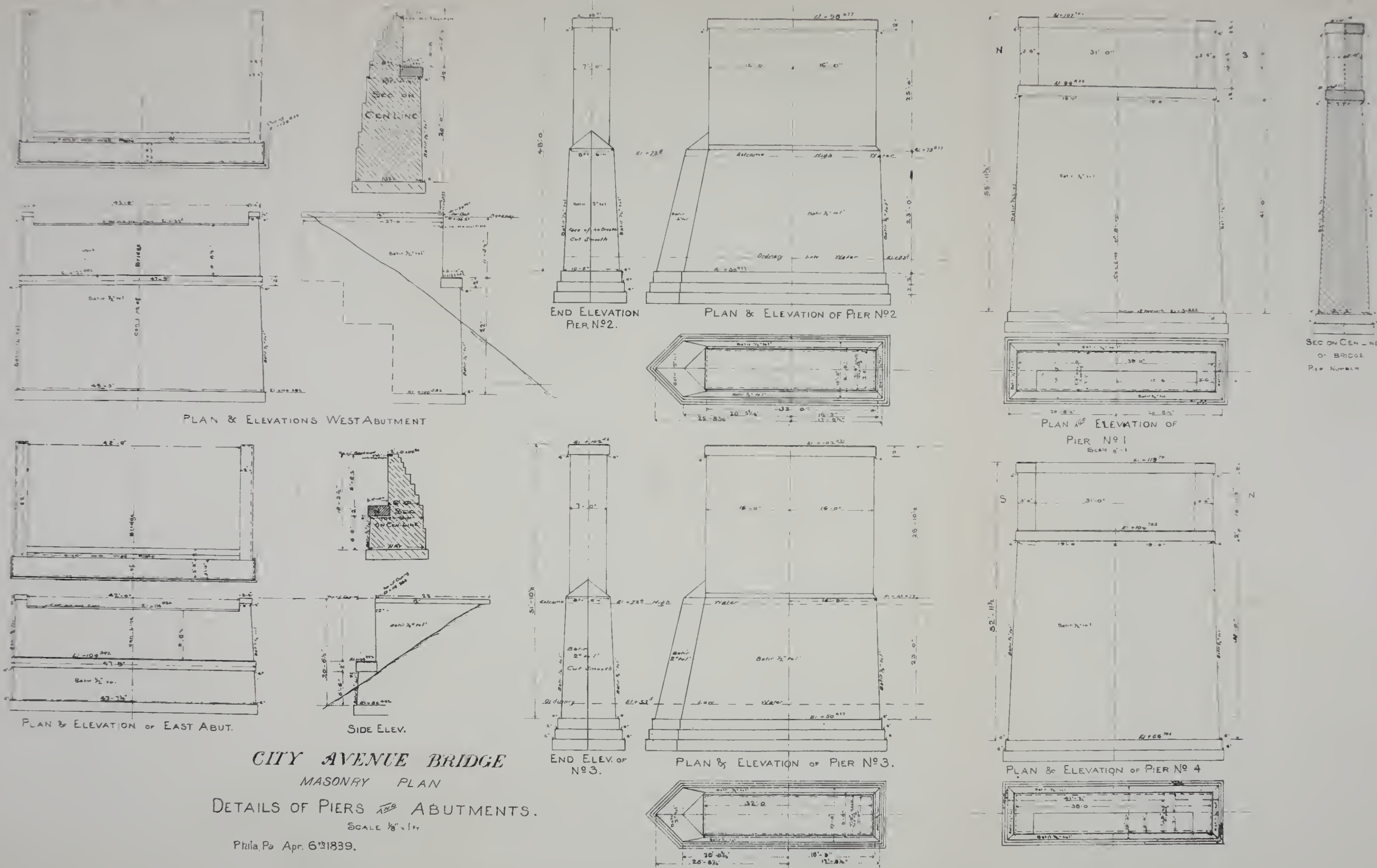
Mr. B. P. Wiltberger read a paper entitled "The Application of Cellulose to Men-of-War and to the Merchant Marine." (To be published.)

Mr. Geo. W. Walker, of New York, exhibited and described an improvement in electric lamps of the "incandescent-arc" type, which is manufactured by the Manhattan General Construction Company, of New York. (The subject is under investigation by the Committee on Science and the Arts.)

The Secretary's report (see Notes and Comments) was presented.

Adjourned. WM. H. WAHL, *Secretary.*


Grade of Roadway 2½ feet per 100
Extreme High Water +72.5
Scale 1"=20'
Ordinary Low Water +53.5
Pier 3
Pier 2
Pier 1
114'-0"
170'-6"
153'-9"
153'-9"
114'-0"
CITY AVENUE BRIDGE
ACROSS
THE SCHUYLKILL RIVER
PHILA.
March 7th 1889.
Approved by the Board of Surveyors
March 18th 1889.
Approved March 2nd 1889
Director of Dept. of Public Works
Approved
Chief Engineer Sup. Fairmount Park
Data for Calculations
Assumed Loading
80 Pounds per sq ft of Roadway & Sidewalks in addition to Weight of Structure
Wind Stresses
Upper lateral bracing
200 lbs per lin ft – static load
100 " " " " – moving "
Lower lateral bracing
100 lbs per lin ft – static
Working Stresses
Tension
Eye Bars 12000 lbs per sq. inch
Plate & Shape Iron 10000 " " " " (net)
Counter Rods 9000 " " " "
Lateral & Sway Rods 15000 " " " "
Compression
Built Members (taking Compression only) 8000 lbs per sq inch
Web Members in three middle panels of End Spans – 5000 lbs per sq inch
Maximum Fibre stress in Pins – 15000 lbs per sq in
6'-0"
15'-0"
14'-0"
16'-6"
10'-6"
2" Y.P. Plank
2" W.O. Plank, laid diagonally
Web ⅜" x ⅜"
12" Flange Plates
Rivets ⅞" dia
SECTION
PIN CONNECTED TRUSSES
SECTION
RIVETED TRUSSES


PLAN & ELEVATIONS WEST ABUTMENT
PLAN & ELEVATION OF EAST ABUT.
SIDE ELEV.
END ELEVATION PIER No. 2.
PLAN & ELEVATION OF PIER No. 2
END ELEV. OF No. 3.
PLAN & ELEVATION OF PIER No. 3.
PLAN AND ELEVATION OF PIER No. 1
Scale 8' = 1
PLAN & ELEVATION OF PIER No. 4
SEC ON CEN LINE OF BRIDGE
CITY AVENUE BRIDGE
MASONRY PLAN
DETAILS OF PIERS AND ABUTMENTS.
SCALE 1/8" = 1 FT
Phila. Pa Apr. 6th 1839.

JOURNAL

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THE CITY AVENUE BRIDGE OVER THE SCHUYLKILL RIVER, PHILADELPHIA.

BY J. VAUGHAN MERRICK.

This bridge, having passed into the hands of the city, and the corporation which built it having been dissolved, it seems proper that so important a municipal improvement should have its history recorded.

For many years past, efforts have been made by those especially interested, to have the Schuylkill bridged at a point near the mouth of the Wissahickon; and old maps of that region show the projected lines for such a bridge, extending from Ridge Avenue immediately south of Wissahickon Creek, upon the eastern side, crossing to a point in line with City Avenue on the western side; which avenue, beginning at a point a few hundred feet from the river, forms the boundary between Philadelphia and Montgomery counties.

Until the completion of City Avenue bridge, no means of communication existed between the two sides of the Schuylkill, from the Manayunk "toll bridge," at the northern end of that suburb, to the "Falls bridge," a distance of about two miles. To both these bridges the approaches from the high table lands on the western side are by hilly and poorly-made country roads. The lower one passes under a low arch on the Reading Railroad, and is dangerous, besides being almost impracticable in winter on account of the grade. The growth of the city in its western wards, in Roxborough and Germantown, called for better facilities of communication between them, and the project of erecting a bridge on the lines above indicated assumed increased importance. As there seemed no probability of getting the city to undertake it, a number of gentlemen, supposed to be interested in promoting its construction, met at the house of Mr. Justus C. Strawbridge, on School Lane, in the latter part of 1887. At this meeting the necessity of better communication was presented and plans were discussed. Two views were advocated, one of which was to connect School Lane by an elevated structure across the Reading (Norristown branch) Railroad and Park Meadow, to the knoll south of the Wissahickon, thence to bridge the Schuylkill; the other for the latter part of this scheme only. For many reasons, on which I need not enlarge, the latter view prevailed, as affording immediate relief at a much lower cost, and also as extending the drives of the park, connecting them with the fine system of turnpike roads in Montgomery County adjoining City Line, and also with West Philadelphia.

A company, under the name of "Germantown and City Avenue Bridge Company," was chartered March 8, 1888, and the first meeting of the Board of Directors was held March 26, 1888. This board consisted of Justus C. Strawbridge, *President*, and J. Vaughan Merrick, George B. Roberts, William P. Henszey, David Scull, Reed A. Williams, Jr., and J. C. Harris, with E. W. Clark, *Secretary and Treasurer*. Subscriptions to the capital stock, amounting to $110,000, were secured. An ordinance was passed by the City Councils and approved by the Mayor (Hon. E. H. Fitler) in June, 1888,

authorizing the erection and location of the bridge, ceding the necessary ground for approach and right of way, upon the approval of the plans by the Department of Public Works, the Survey Department and the Commissioners of Fairmount Park. By this ordinance the city reserved the right to purchase the bridge at cost, upon a sworn statement thereof at completion, or to lease it at five per cent. thereupon, and also to pay the State tax and maintain it in good repair. The Mayor was to exercise this option within two years of the completion.

After careful surveys had been made as to the location of approaches and river soundings, several plans were successively prepared and considered, questions of cost entering largely into their consideration. Finally, the company determined upon a five-span bridge with plank floor, and adopted a plan prepared by W. H. Brown, Esq., assisted by Mr. H. A. Pratt. This plan was approved by the authorities above named, and is the one on which the bridge was built. The total length is 706 feet, viz.: two end spans of 114 feet; three channel spans of 170 feet 6 inches (west), 153 feet 9 inches, and 153 feet 9 inches respectively. Width of roadway, 30 feet, and two sidewalks, 6 feet each; a total width of 42 feet; Pratt truss for channel spans; roadway on upper chord; piers of cut stone from Conshohocken quarry; superstructure of iron; road and footways of plank (two thicknesses), and an ornamental iron railing and lamp-posts on each side. The strength of the superstructure is equal to that usually required for railroad bridges, and, therefore, far in excess of the proportions commonly adopted for highway bridges. In all the details of design and construction, consultation was had with the (then) head of the Survey Department of the City of Philadelphia, the late Samuel L. Smedley, and his approval obtained. The bridge is of considerable height, and its roadway is inclined 12 feet, being $77\frac{3}{4}$ feet above mean low water at the western end, and $65\frac{3}{4}$ feet at the eastern end.

The data for calculations were as follows:

Assumed loading, 80 pounds per square foot of roadway and sidewalks, in addition to weight of structure.

Wind stresses, on upper lateral bracing, 200 pounds per lineal foot, static load; 100 pounds per foot, moving load.

Working stresses, tension, eye bars, 12,000 pounds per square inch.

Working stresses, tension, plate and shape iron, 10,000 pounds per square inch.

Working stresses, tension, counter rods, 9,000 pounds per square inch.

Working stresses, tension, lateral and sway rods, 15,000 pounds per square inch.

Working stresses, compression, built members (taking compression only), 8,000 pounds per square inch.

Working stresses, compression, web members in three middle panels of end spans, 5,000 pounds per square inch.

Maximum fibre stress in pins, 15,000 pounds per square inch.

The company contracted for the stone-work, after public advertisement, and awarded the same to the lowest bidder, John B. Reilly & Co.

The iron work was submitted to eight first-class railway bridge builders, and the contract was awarded to Cofrode & Saylor, the lowest bidders conforming to the specifications. The board appointed as a building committee, Messrs. Merrick, Roberts and Henszey; and elected Frederick J. Amweg, C.E., as the constructing engineer. Under his charge the work was completed, and the two approaches in Fairmount Park graded, macadamized and planted. The total cost of the entire work, including expenses of organization and interest upon advance payments up to completion, was $109,807.42.

Work was begun in April, 1889, and was to have been completed in five months; but owing to delay in beginning the stone-work, and excessive and repeated floods during the summer, which carried away the coffer dams, it was not opened for travel until May 30, 1890, and was finally completed October 1, 1890, when a statement of cost, as above, was filed with the city.

The traffic upon the bridge immediately showed the wisdom of its projectors, and justified their belief that it was

greatly needed. It earned from the beginning four per cent. on its cost after paying all expenses; and travel gradually increased, until five per cent. was earned at the time (1893) the Falls bridge was carried away by freshets. After that date, of course, the increase was more rapid, as all adjacent travel was thrown upon it.

In their dealings with the company, the city authorities have not appeared to recognize the public spirit of the projectors of the enterprise, or the benefits it would secure, in the development of suburban territory and the convenience of the traveling public.

The ordinance granting permission for its erection prescribed, as has been stated, certain terms upon which it might be bought or leased, which terms simply secured the subscribers against loss. When, however, the Mayor elected to lease it, Councils offered inferior terms to those prescribed by their own ordinance, and less than the bridge was already earning. The offer was, of course, declined.

Some months later, December 28, 1892, certain citizens on the west side and others, unconnected with the company, began proceedings before the Court of Quarter Sessions to compel the city to free the bridge from tolls, under the State Act of May 8, 1876, providing for such cases.

The Court (BIDDLE, J.) decided, December 5, 1893, that these proceedings should be set aside, on the ground that, although the act provided for taking bridges in any county in the State, yet that Philadelphia County having been erected into a municipality, the act thereby ceased to be operative therein. The case was carried to the Supreme Court of Pennsylvania, when the action of the lower court was reversed on the ground that Philadelphia was still a county, and its citizens could not be deprived of the only means for freeing bridges which had been provided by the Legislature. New proceedings were ordered October 22, 1894. The case was accordingly brought before the Grand Jury by Judge Reed, when, on November 2, 1894, the bridge was ordered to be taken for public use at a valuation equal to its cost. Possession was given on November 20th, the city retaining the tolls collected to that date from the 2d inst.

The accompanying illustrations show a structure which will compare favorably, either in appearance or strength, with any bridge erected by the municipality. As to cost, it is, of course, impracticable to make a fair comparison, owing to the diverse conditions existing in different bridges. But it is certain that the expense incurred in its construction is far less than would have been possible under city contracts. It was built by business men, who gave their services without compensation, and upon methods calculated to ensure a minimum cost with the most direct responsibility. Separate contracts with principals, for stone-work and superstructure, instead of one contract for the whole work, enabled the company to obtain the most economical results from the best bidders.

The Redheffer Perpetual Motion Machine.

By Henry Morton.

In the museum of the Franklin Institute, at Philadelphia, is a curious model, which was made about eighty years ago, by Isaiah Lukens, for the purpose of exposing the fraud involved in the (then) famous Redheffer Perpetual Motion Machine, in which large sums of money were sunk, as they have been more recently in the "Keely Motor" and like schemes.

This model, represented in the accompanying engraving, consists of a horizontal circular table, attached to, and supported by, a central vertical shaft, resting on a pivot below and steadied by a journal held in a framework above. Two inclined planes, mounted on wheels, rest on this circular table, and each inclined plane has on it a car containing two removable weights.

The inclined planes, and also the cars, are attached to levers which are supposed to transmit to the central shaft the tendencies of the inclined planes to run from under the cars, and of the cars to run down the inclined planes, and

these tendencies are supposed to cause rotation of the central shaft, carrying with it the table and all the parts on it.

A model identical in appearance with this was for many years exhibited in the Philadelphia Museum, but was destroyed when that museum was burned down. In that model, if the weights were taken out of the cars, the machine would come to rest, but would start up again as soon

Isaiah Lukens' model of the "Redheffer Perpetual Motion," in the collection of the Franklin Institute.

as they were replaced, and under favorable conditions would continue to run indefinitely.

Here is a phenomenon which might well startle a novice, but he would do well to hold fast to his faith in the conservation of energy, and to insist on a further investigation into the interior of the apparatus; for this is what such an investigation would reveal:

A train of clock-work, driven by a spring, was concealed

in the base of the machine, and could be wound up by a slight movement of one of the ornaments on the frame of a glass case, which covered and *locked up* the model beyond seeming possibility of tampering. This clock-work drove a small plate, on which rested the pivot of the central vertical shaft; and the various frictions were so adjusted, that when the cars were loaded, the weight thus added would increase the friction of the little plate sufficiently to drive the shaft; but when the weights were removed, this friction was too slight. An attendant, touching the outside case for a moment, once a day, under pretence of dusting or the like, could keep the spring wound up perpetually.

Such, then, is the structure, and such the mode of operation, of this very ingenious model, whose history, which is also extremely interesting, I will now give.

In the year 1812, Mr. Charles Redheffer applied to the Legislature of Pennsylvania for a grant of funds to carry out his great invention of perpetual motion, and a committee of experts, consisting of Messrs. Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wernwag, Josiah White and Samuel D. Ingham, was appointed to examine the matter.

The machine to be examined was set up in a building near the banks of the Schuylkill River, in Philadelphia, and, on a day appointed, the above-named commissioners went out to inspect the apparatus, Mr. Nathan Sellers taking with him his son Coleman, afterwards the father of Prof. Coleman Sellers, E.D.

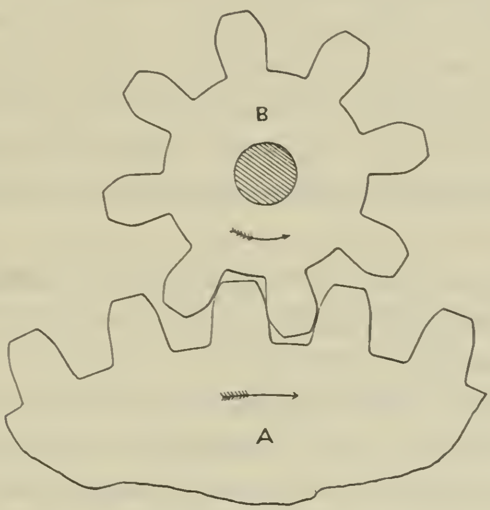
When the Commissioners arrived at the place they found that the door of the room containing the machine was locked and the key missing, so that their study was confined to an inspection of the apparatus through a barred window.

Even this limited view, however, was enough for the sharp eyes of Coleman Sellers. The machine had a set of teeth on the periphery of the rotating table, which geared into another wheel, whose axle was supposed to transmit the power to some other point where work was to be done.

Young Sellers, looking through the window, noticed that

the faces of the teeth in the two wheels were polished by wear *on the wrong sides.* This will be clear from a glance at the accompanying diagram. Let *A* be the rotating table driving the gear wheel *B*, in the direction of the arrows; then, clearly, the front faces of the teeth of *A* will press against the rear faces of the teeth of *B*, and these faces will be polished by friction.

If, however, it is the front faces of the teeth of *B*, and the rear faces of those of *A*, that are polished, it is manifest that *B* must be driving *A*. This is what young Sellers noticed, and pointed out to his father, as proving that the perpetual motion machine, instead of driving the gear



wheel, was being driven by it, from some concealed source of power.

Satisfied, by this observation, as to the fraudulent character of the Redheffer machine, Mr. Nathan Sellers concluded that others might be best satisfied by a sort of homœopathic object lesson.

He, therefore, went to Mr. Isaiah Lukens, a very skilful mechanician of that day, and had him construct the above-described model. This he exhibited at first to a number of persons, including Mr. Redheffer himself, but without explaining its true "inwardness." Mr. Redheffer was so impressed, that he privately offered Mr. Sellers a large share of his inventions if he would tell him "how it was done."

It is hardly necessary to say that this offer was declined, and that in due time the true *modus operandi* was made public.

This matter is in many respects so curious, that I will here insert a copy of the resolution, under which this commission acted, viz.:

"WHEREAS, The interference of the Legislature of Pennsylvania in causing an inquiry to be made relative to the perfection or imperfection of newly-invented machinery is not without precedent;

"AND WHEREAS, It has been represented that Charles Redheffer, of the County of Philadelphia, has invented a machine declared, not only by the inventor, but by many intelligent persons, to possess the power of self-motion;

"AND WHEREAS, Should it be ascertained that these opinions are correctly founded, not only great honor would be conferred upon the Commonwealth, but incalculable advantages would be derived from the invention by the people of the United States especially, and by mankind in general;

"AND WHEREAS, On the other hand, should the machine be found to be imperfect, the public interest would be promoted by exposing its fallacy;

"AND WHEREAS, The Legislature of this Commonwealth reposes confidence in the integrity and qualifications of Henry Voight, Robert Patterson, Nathan Sellers and Oliver Evans, of the city of Philadelphia; Archibald Binney, Lewis Wernwag and Josiah White, of the county of Philadelphia; and Samuel D. Ingham, of the county of Bucks;

"*Therefore, Resolved,* By the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, that Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wernwag, Josiah White and Samuel D. Ingham be, and they are hereby, requested to make a strict examination of the machine invented by Charles Redheffer, and to make specific representation respecting it, as its alleged importance and the public expectation require.

"*Resolved,* That the Secretary of the Commonwealth be, and is hereby, requested to transmit a copy of the foregoing

preamble and resolution to each of the persons named therein, and also to Charles Redheffer.

[SIGNED] JOHN TOD,
Speaker of the House of Representatives.
P. C. LANE,
Speaker of the Senate.

"In the House of Representatives, December 14, 1812. Read and adopted.

GEO. HECKERT,
Clerk of the House of Representatives.

"In Senate, December 17, 1812. Read and adopted.

JOSIAH A. MCJIMSEY,
Clerk of the Senate."

Then follows the certificate of the Deputy Secretary, and his letter to Nathan Sellers.

In the "History of Philadelphia," by Scharf and Westcott, Vol. I, it is stated that, on November 26, 1812, City Councils appointed a committee to examine into the Redheffer invention. It is also stated that January 21, 1813, was appointed for the examination of the machine, but, before the day mentioned, Redheffer notified the committee that it would not be convenient for him to be present; afterwards he said that he would not show the machine at all, and this being reported to the Legislature, the committee was discharged.

The champion of Redheffer in the public press of that day was the *Aurora*, as in more recent times the New York *Herald* was, of Keely.

THE RISE AND PROGRESS OF RIVER AND HARBOR IMPROVEMENT IN THE UNITED STATES.*

BY I. Y. SCHERMERHORN, C.E.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

History teaches that the early centres of population have always been around the mouths of great rivers. As population, in time, spreads from such centres, the need for national intercommunication makes these rivers the natural highways of the nation. With a higher national development, and its larger requirements, the capacity of these water highways, in many cases, falls below the demand placed upon them, and their improvement to meet these larger requirements becomes a necessity.

Under modern civilization, no better material criterion of a nation's advancement can be furnished than the measure of facilities provided for ready intercommunication. By such means, the products of different parts of the country can be freely interchanged, and the varying needs of one locality met by the resources of another; while equally, if not in a larger measure, they contribute to national development by bringing otherwise widely-separated parts into closer relations, thereby breaking down provincialism, and knitting the nation together in a bond of unity, established upon national and not local interests.

The utilization for commercial purposes of the waterways of our country is so important a factor in our national growth and prosperity, that the student of political economy cannot fail to be interested in the motives which have prompted, and the steps which have led to, the present stage of development of our navigable waters; and when attention is directed to the importance of such water high-

* A lecture delivered before the Franklin Institute, December 21, 1894.

ways, in the earlier development of the country, and their still greater value to its full development under the conditions of to-day, it will readily be admitted that such national highways are not secondary in importance to any other, not even excepting our wonderful system of railroad intercommunication.

The present national policy as to the conservation and improvement, by the general Government, of the navigable waters of the United States has been the growth of a century's action and legislation; and, though this policy began with feeble indications of purpose, it has nevertheless steadily grown in force and definition, until it has culminated in the broad clear conclusions and position of the present day. While we believe that the beginning must contain all the potentiality found in the thing into which it has developed, it is frequently difficult to recognize the beginning in the end, unless we consider the intermediate stages. That you may the better compare the beginning with the end, I propose to first briefly place before you, in general terms, the position which the general Government assumes, in its broad claim of conservation and supreme control, over the navigable waters of the country, and then to trace the steps by which such a commanding position has been reached.

In earlier times, the waterways which were denominated navigable, and over which the Government assumed to exercise control, were limited to the Great Lakes and the more important waters in which the tide ebbed and flowed. Now, the term navigable waters is made, by the Acts of Congress and the decisions of the United States Supreme Court, to cover the Great Lakes and their direct tributaries, the connecting links between these lakes, and all other waters, whether tidal or not, upon which, directly or indirectly, the Government has entered for the purpose of their improvement, and which have a navigable capacity sufficient to float rafts, skiffs and saw-logs.

Over all such waters the conserving control of the Government is supreme, and without the authority of the Secretary of War, who is made, by the Acts of Congress, the cus-

todian of the navigable waters of the land, no bridge or dam can be built, or other structure erected, which would impair the free navigation of such waters; no material of any kind can be added to or taken from their beds, which will in any way modify their natural capacity, even though such additions or removals be made for the improvement of such waters by the riparian owner. For any act which will in any manner interfere with the natural condition of our navigable waters, or their navigable capacity, the authority of the Secretary of War must first be obtained.

These waters are the nation's highways, and as such are free to all, whether it be to float modern steamships, or only skiffs and saw-logs. The riparian owner may probably make some theoretical claim of ownership to its bed by erecting wharves and landings, so long as such structures in no way, directly or indirectly, invalidate the navigability of the waters; but there his privilege ends and the broad rights of the public begin, and there the National Government stands on guard over these paramount public rights. The power of Congress to guard against the perversion of the uses of a street in the city of Washington, or against any act tending to impair its usefulness to the general public, is no more supreme on such streets than it is over the navigable waters of the United States.

The accumulated force of the decisions of the United States Supreme Court, beginning with those of Chief Justice Marshall, who first outlined this policy, and coming down to those of recent times, leads to the conclusion that in this matter of the conservation and control of the navigable waters of the country, the States can in no manner exercise such control, but, instead, the power of Congress is complete, absolute and exclusive, and may be exercised to its fullest extent, and with no limitations beyond those prescribed by the Constitution.

This, in brief, is the position held by the national Government to-day, and under the conclusions which may be derived from the broad premises, this control of the Government is exercised, and the works of river and harbor improvement planned and executed. Let us now return to

the early views held upon these same questions, and trace the rise and progress toward the system of to-day, as summarized in the foregoing statements.

The fundamental English theory was, that the rivers and bays of the kingdom existed only for the purpose of floating the king's ships and furnishing salmon and turbot for the royal table; therefore, the title of all ebbing and flowing streams was in the king alone. The principle which was in force in England became equally applicable in her colonies, and the early colonial title to the waters of this country was resident in the sovereign. When the colonies revolted and finally secured their independence, each State, as a separate sovereign, maintained that it had inherited all the rights of the original sovereign, and among these, supreme control over the navigable waters within its borders.

In streams in which the tide rose and fell, low-water mark in some States and high-water mark in others, was the limit of the riparian owner's rights, and outside of such limits the State owned the bed of the stream, and, as such owner, exercised the right to lease or sell to individuals the exclusive privilege of using the State's water domain for certain purposes. Many of the Atlantic Coast States exercised these rights to very recent times, and New Jersey and Delaware still claim the right to maintain the fishing privileges sold to individuals long ago. While such rights are passively recognized by the general Government at the present time, they are not permitted to interfere with any plan for the improvement of the nation's navigable waters; and if such plan of improvement destroys the value of these rights, it is an injury without damages, since the nation's right to improve its navigable waters, or adopt any means to maintain such improvements, is paramount to any right which the State or individual may claim in such waters.

Under the "Articles of Confederation," which existed from 1777 to 1789, Congress had no power over commerce or navigation, and, accordingly, each State exacted such laws as it pleased. Rivalries existed whereby one State competed with another: one, by more favorable navigation

laws, sought to increase its own trade and commercial advantage, at the expense of sister States; and the struggle for commercial existence became simply a question of the survival of the fittest. Such a condition of affairs could not long exist, without producing the unfortunate results sure to flow from lack of co-operation and harmony, in matters which affected the body politic, and, as a result, the first amendment to the "Articles of Confederation," proposed to give Congress enlarged powers over the subject of commerce and navigation.

This early experience of the States in attempting to regulate commerce by the individual action of the States having resulted in a degraded and disorganized condition of commerce, and thereby proven a failure, upon the adoption of our National Constitution in 1789, there was, among the States, but one opinion upon this question, and that was, that "Congress should alone have power to regulate commerce among the several States." From this seemingly general and apparently indefinite provision, has grown the Government's broad assertion of power and its emphatic enforcement, over the navigable waters of the United States as it exists to-day. The power conferred on Congress to regulate commerce among the States has been repeatedly interpreted by the Supreme Court to mean that, as the greater always includes the lesser, this power includes navigation, and therefore extends to the navigable waters whereon commerce is carried. The full realization of all that was contained in this power to regulate commerce among the several States, was probably never anticipated by those who framed our constitution, and its application of to-day has been a slow evolution of policy from the environment of circumstances which have grown up around the nation in the first century of its life.

Let us now examine the early condition of affairs which surrounded the nation upon the adoption of this constitutional provision, and the efforts which were made by legislation to regulate commerce among the States. Prior to its adoption, in 1789, the States of Rhode Island, Maryland and Georgia had authorized the collection of a tonnage tax

on the commerce of some of their rivers, and the revenue derived from this tax was applied, by the States, to the removal of wrecks and other obstructions to navigation. In 1790, Congress officially gave its consent to this action of the States, for the term of one year.* By subsequent legislative action, this consent was extended yearly for some time. In 1798, a similar consent was given to the action of the State of Massachusetts, whereby Tobias Lord had been authorized to build a pier at the mouth of the Kennebunk River, and collect a duty on vessels using the pier.† In 1806, Congress gave assent to our State legislation which had empowered the Port Wardens of Philadelphia to collect a duty of 4 cents per ton on all vessels clearing from this port for any foreign place whatever; the moneys thereby obtained were to be applied to improving the Delaware River.‡

Acts of this kind were continued down to 1828, and then ceased. After 1814 it was stipulated in these Acts that this tonnage duty should not apply to vessels propelled by steam and employed in the transportation of passengers. To the beginning of the present century Congress had, except by such Acts as these, manifested no tendency to enter upon the improvement of our navigable waters, and it was from these feeble efforts of the States to help themselves, that our present policy of internal improvements has arisen.

At the beginning of this century Philadelphia, with its population of 81,000, was the most populous of our American cities, and the nation's capital; and it is of interest to note that the first appropriation ever made by Congress for the improvement of waterways, was made in 1802, by the appropriation of $30,000 for the erection of public piers in the river Delaware.|| Since that date, $7,000,000 has been appropriated for works of improvement in the harbor, river and bay.

The early revenue of the country was small, and after

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* Act of August 11, 1790.

† Act of March 27, 1798.

‡ Act of February 28, 1806.

|| Act of April 6, 1802.

providing for the current expenses of the government, there was probably no balance to apply to other purposes; nevertheless, the importance of developing the navigable waterways seemed to have impressed itself upon Congress, and means were sought to accomplish such an object. In 1819, Congress provided that five per cent. of the proceeds derived from the sale of lands in the territory of Alabama, should be reserved and applied to making public roads, canals and improving the navigation of rivers in that territory.*

The paramount importance of the commerce of the Delaware River and Bay is again emphasized by the appropriation, in 1822, of $22,700 for the beginning of two piers in Delaware Bay, near Cape Henlopen, of sufficient dimensions for a harbor of refuge.† This was the commencement of the Delaware Breakwater, the first of its kind in the United States, and upon which work has been in progress up to the present time, by an expenditure of $2,728,000.

In 1824, the President was authorized to have surveys and estimates made of such roads, canals and rivers as he might deem of national importance, and when such surveys were finished, to report the results to Congress. This work was completed in the next year, and, apparently as a result, in 1825, the Secretary of the Treasury was authorized to subscribe, in the name of, and for the United States, to 1,500 shares of the capital stock of the Chesapeake and Delaware Canal Company, and was instructed to vote on these shares in the name of the United States, for the election of the officers of the company.‡ In 1826, similar subscriptions were authorized to the stock of the Louisville and Portland and to the Dismal Swamp Canal.|| In these Acts, again we see the interest of Congress in internal improvements and its desire, by co-operation at least, to stimulate enterprise and prosperity through the development of navigable highways.

Although since 1804, as we have seen, small appropria-

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* Act of March 2, 1819.

† Act of May 7, 1822.

‡ Act of March 3, 1825.

|| Act of March 13 and 18, 1826.

tions had been made, from time to time, for the improvement of navigation at a few points, it was not until 1826, or during the administration of John Quincy Adams, that the first approach was made to the passage of a river and harbor bill, aggregating about $150,000 and applicable to about twenty localities.* (The river and harbor bill of 1892 aggregated about $22,000,000, and was applied to 425 localities, exclusive of surveys and examinations at 145 localities.)

From 1826 to 1838, or to the close of the administration of Andrew Jackson, Congress continued to make annual appropriations for the improvement of a number of rivers and harbors, expending, during this interval, about $9,000,000. While the number of works for which appropriations were made was not large, there is, nevertheless, evidence in these bills that the policy of improving the navigable waters of the country had been clearly decided upon, and the work inaugurated under a carefully-considered and well-devised system.

In 1841, Congress provided that to each new State thereafter admitted to the Union, 500,000 acres of public land should be set aside, the proceeds of the sale of which was to be faithfully applied by the State to the building of bridges and the improvement of roads, canals and watercourses, over which the United States should have the right to transport, free of toll, its mails, troops and munitions of war.†

After what seemed to be the inauguration of annual river and harbor appropriations, between 1826 and 1838, we find, after the latter date, a change in public policy, extending to the time of the complete re-establishment of the Union, in 1866. During this interval of about twenty-six years, only three regular river and harbor bills were passed, viz.: in 1844, 1852 and 1864. Appropriations were made in the other years, but they were small and seem to have been mainly applied to a few localities, and there to the repair and maintenance of work previously commenced. The

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* Act of May 20, 1826.

† Act of September 4, 1841.

total amount appropriated, during this interval of twenty-six years, was only $6,600,000, or about 70 per cent. of the amount appropriated in the previous thirteen years, from 1826 to 1838.

After the close of the civil war, and the return of the country to peace and industrial activity, in 1866, the pent-up energy of our resources made apparent the need for improved water highways and their accompanying facilities, for the fuller development of our national growth. This era, as in other directions, marks a new departure in river and harbor improvement, and to this date, may properly be assigned the beginning of a policy, which has since steadily expanded to its present position. The importance of this period, from 1866 to the present, may better be realized through the statement that, during this twenty-nine years, about 94 per cent. of all moneys for river and harbor improvements have been appropriated.

From 1866 to 1882 inclusive, excepting only the year 1877, annual river and harbor appropriations were made, usually in yearly-increasing amounts. From 1882 to 1894 inclusive, the appropriations for the regular river and harbor bill were biennial, and passed during the even years, or the first session of each Congress. By the river and harbor act of 1890, the Secretary of War was authorized by Congress to enter into contracts for the entire completion of certain-named important improvements, under predetermined plans and estimates of cost, and to be carried on under such contracts as Congress shall, from time to time, make appropriations therefor. Since 1890, the number of works placed under these conditions has been, from time to time, increased, until at the present they number eighteen, and include such important works as the harbors of Galveston, Mobile, Charleston, Savannah, Baltimore and Philadeiphia; Point Judith Breakwater, Humboldt Bay, Hay Lake Channel; and the rivers, Hudson, Great Kanawha, Saint Johns, Mississippi, Missouri, Saint Marys, Columbia, and channel between Chicago and Duluth.

After works have been placed by Congress under the provisions of these continuing contracts, appropriations

therefor are withdrawn from the regular river and harbor act, and thereafter provision is made for them by appropriations contained in the Sundry Civil Act, which is annually passed by Congress to cover liabilities previously authorized, and to be incurred during the following fiscal year. The appropriations made for this class of works, since their inauguration in 1890, is $26,331,343. The aggregate of these two classes of appropriations constitutes the amount applicable to river and harbor improvement, although provided in entirely different Acts. It is believed that this method of carrying on important works of improvement by continuing contracts, has resulted in marked economy to the nation, and advantage to the commercial interests involved; the former, arising from the ability of the government to make such continuing contracts at lower rates than would obtain under the other methods of making contracts for the expenditure of each separate appropriation; and the latter, by giving an assurance to commercial interests of the ultimate and earlier completion of the improvement. The favor with which this method of providing for the important works has been received, leads to the expectation that it will eventually be adopted upon all the principal works of river and harbor improvement.

Year.	Amount Appropriated.	No of Works.	Year.	Amount Appropriated.	No. of Works.	Year.	Amount Appropriated.	No. of Works.
1820	9,500	2	1845	65,700	5	1870	4,197,400	98
1821	2,600	2	1846	25,000	1	1871	5,374,500	116
1822	22,700	1	1847	14,900	4	1872	5,888,000	150
1823	6,100	2	1848	65,000	2	1873	7.353,000	140
1824	115,000	3	1849	25,500	4	1874	5,228,000	142
1825	59,100	3	1850	75,000	2	1875	6,648,500	161
1826	155,400	20	1851	30,000	1	1876	5,015,000	151
1827	160,400	15	1852	2,141,300	103	1877	1,000,000	1
1828	640,100	30	1853	51,800	2	1878	8,322,700	218
1829	339,800	40	1854	291,500	5	1879	9,577,500	254
1830	357,200	25	1855	221,800	5	1880	8,976,500	340
1831	633,600	34	1856	832,100	8	1881	11,451,300	372
1832	699,300	35	1857	75.800	4	1882	18,988,900	370
1833	540,900	26	1858	87,500	3	1883	—	—
1834	774,000	33	1859	65,800	3	1884	14,948,300	316
1835	508,100	25	1860	12,700	2	1885	—	—
1836	1,157,200	77	1861	160,000	3	1886	14,464,900	342
1837	1,366,700	52	1862	115,000	2	1887	—	—
1838	1.535,500	59	1863	121,900	2	1888	22,397,600	398
1839	45,600	7	1864	647,800	9	1889	—	—
1840	1,100	1	1865	373,000	4	1890	25,136,300	436
1841	156,900	8	1866	3,881,100	57	1891	2,951,200	6
1842	187,000	5	1867	4,922,300	66	1892	22,068,200	435
1843	277,200	11	1868	1,676,500	37	1893	14,166,200	17
1844	722,600	33	1869	2,300,000	50	1894	20,043,200	408

The preceding table, compiled from the Acts of Congress, shows the amount annually appropriated, from 1820 to 1884 inclusive, for the improvement of rivers and harbors, and also the number of works, or localities, for which the appropriations were made.

The following summary of appropriations made for river and harbor improvements by decades, from 1820 to 1894, will probably more clearly present the question of their growth than any other verbal statement:

Amount appropriated from 1820 to 1830	$1,510,700
" " " 1830 to 1840	7,618,100
" " " 1840 to 1850	1,536,900
" " " 1850 to 1860	3,872,600
" " " 1860 to 1870	14,110,300
" " " 1870 to 1880	58,604,600
" " " 1880 to 1890	91,227,600
" " " 1890 to 1894	84,365,100
Total	$262,845,900

Or, otherwise expressed, as much money was appropriated in the ten years between 1860 and 1870 as had been appropriated in the previous forty years. Between 1870 and 1880, the amount appropriated was more than twice the aggregate of the appropriations for the previous fifty years; while, for the ten years, from 1880 to 1890, the appropriations were 60 per cent. more than those of the previous ten years, and in excess of the aggregate for the previous sixty years. From the amount already appropriated in the present decade and the ratio furnished by the past, it seems fair to assume that, by its end, the appropriations will have reached, for this decade, fully $200,000,000. With such a policy applied to such possibilities as we have, who can say what the next fifty years will produce in their feature of river and harbor improvements?

The planning and execution of these works of river and harbor improvement is a part of the duty of the Corps of Engineers of the Army, which is practically a bureau of the War Department, of which the Secretary of War is the head. In this work the entire country is divided into five divisions, viz.: the Pacific, Northwest, Southwest, Northeast

and Southeast; and over each is placed one of the senior officers of the Corps, usually with the rank of Colonel, in the capacity of Supervising Engineer. These five divisions are further subdivided into from forty-five to fifty districts, each in charge of an officer of the Corps, and generally known as the local Engineer-in-charge of river and harbor improvement. The official head of the Corps is the Chief of Engineers, with the rank of Brigadier General.

Plans and projects for improvements, with estimates of cost, and also all reports upon examinations or surveys called for by Congress, are submitted by the local engineer of each district to the Supervising Engineer of the division, by whom they are transmitted to the Chief of Engineers, with such comments as, in the judgment of the Supervising Engineer, may be necessary. At least once in each year, the Supervising Engineer visits each district in his division and, accompanied by the local Engineer-in-charge, makes a careful inspection of all works in progress.

Upon the works of river and harbor improvement there are now engaged, exclusive of the Chief of Engineers, about 77 officers, with the following rank, viz.: 6 Colonels, 9 Lieutenant-Colonels, 15 Majors, 18 Captains, 21 First Lieutenants and 8 Second Lieutenants. The Second Lieutenants of the Corps, after being graduated from a four years' course at West Point, are assigned to a post-graduate course of three years at Willetts Point. This course is essentially a school of practise under the tuition of officers of the Corps, in which the young engineer is taught to co-ordinate his theoretical knowledge with its practical application to the arts of fortification, defenses, and river and harbor improvements. As a further preparation for active practise, he is often subsequently assigned to duty under a senior officer as an assistant upon constructive works, thereby passing through a novitiate, which well prepares him for the active practise of his profession.

The administration of the works of river and harbor improvement requires the employment of large number of civilians, in the capacity of assistant engineers, surveyors and draftsmen; and a large and able body of men has been

drawn from the civil engineers of the country to fill these positions. To supply the increasing demand for such service, nearly all of our engineering schools have introduced into their courses, instruction relating to river and harbor improvement.

The method of carrying on these river and harbor improvements at the present time may be summarized as follows: Congress having previously made appropriations for works in certain localities, we find these works in progress. At the close of each fiscal year, the local engineer of a district submits, through the Supervising Engineer of the division, to the Chief of Engineers, a report upon each work in his district, embodying statements as to the project under which the improvement has been carried on, details of work done, with recommendations for work further proposed under the project, together with a statement of the amount of money which can profitably be expended in the fiscal year following the one upon which he is entering.

Upon the receipt of these reports, they are transmitted to the Secretary of War, by the Chief of Engineers, with a report on each work containing such recommendations as he deems proper, and with a statement of the amount of money required for continuing the work through the year for which appropriations are yet to be made. These combined reports are then submitted to Congress by the Secretary of War as a part of his annual report.

During the sessions of Congress, these reports are carefully considered by a committee in the Senate known as the "Committee on Commerce," and in the House, as the "Committee on Rivers and Harbors," and a bill, denominated "An act making appropriations for the construction, repair and preservation of certain public works on rivers and harbors and for other purposes," is finally drawn and passed by Congress, and approved, or otherwise, by the President.

This bill contains specific amounts for each work named, sundry legislation pertaining to navigable waters, such as has been previously alluded to, and a list of new localities for which Congress directs preliminary examinations or surveys to be made. No new works of improvement can be

undertaken until an appropriation has been specifically made therefor, and such appropriations cannot be made until the local engineer has made a preliminary examination, and, together with the division engineer, shall have reported to the Chief of Engineers that in their judgment the river, harbor, or locality, under examination, is worthy of improvement by the Government, with reasons and facts for such opinion, and the present and prospective demands of commerce for such improvement: and further, if worthy of improvement, what it will cost to make a survey of the same, with the view of submitting a plan for its improvement, with an estimate of the cost thereof. The Chief of Engineers is required to submit to Congress, through the Secretary of War, all such reports of the preliminary examination, together with his views thereon, and his opinion of the public necessity or convenience to be subserved by the proposed improvement.

Should the river, harbor or locality have sufficient merit under all these requirements to run this triple gauntlet successfully, Congress, if it approves, may order a survey to be made, the results of which are, in a similar manner, transmitted to Congress, with a detailed plan of improvement and estimate of cost, as determined from such a survey. Should this survey justify the previous opinion held at the time of the preliminary examination, Congress may, at its next session, make an appropriation for commencing the improvement. This method results in the survival of the fittest, and prevents the expenditure of public moneys upon localities that have no merit as public improvements.

Having briefly followed the rise and progress of river and harbor appropriations, and the method of their application, let us turn to some of the leading principles which have been developed by legislation upon the subject of the navigable waters of our country.

Although the policy of improving our navigable waters by government appropriations dates back to nearly the beginning of this century, there was until lately little, if any, legislation by which the right of the Government was claimed to conserve and control its navigable waters. Leg-

islation of this class has been enacted mainly during the past ten years.

The legislation which is of most interest and which best illustrates the general position which the Government has assumed in the entire question, is that relating to its broad denial of the right of any individual, corporation or municipality, city or State, to in any manner interfere with the free and safe navigation of any navigable waters of the United States, without the consent and authority of the Government.

No bridge can be built across, or abutments placed in, such waters prior to the approval by the Secretary of War, of the specific plan and location proposed for such bridge.* This supervision regulates the length of fixed spans, the width of draw-span openings, the clear height under the bridge and the position of the abutments. After the bridge is completed, the same authority prescribes rules and regulations governing the opening of any draws therein for the proper passage of vessels, and imposes heavy fines and penalties for their infraction.† Bridges previously built, and which are found to obstruct navigation, are required to be altered upon notice by the Secretary of War, so as to render navigation through or under such bridges safe, easy and unobstructed.‡ Any bridge which presents difficulties to navigation, or to passage of rafts through its draw or raft-spans, shall be provided with satisfactory aids to the passage of such spans.|| In the matter of water, gas or oil pipes, laid across the bed of any navigable waters, these, in like manner, are subject to the control and authority of the Secretary of War.

The Secretary of War has authority, in any waters which he may consider it desirable, to establish harbor lines, beyond which no piers or wharves shall be extended or deposits made, except under such regulations as he may prescribe from time to time; and no wharves, piers or other con-

* Acts of September 19, 1890; July 13, 1792.

† Act of August 18, 1894.

‡ Acts of August 11, 1888; September 19, 1890.

|| Acts of July 5, 1884; August 11, 1888.

structions can be placed in any navigable waters where such harbor lines have not been established, except by permission of the Secretary of War;* all structures previously placed, and which obstruct or impair navigation or commerce, are declared by the Acts of Congress to be unlawful structures.† In mining districts, deposits or dèbris of mines or stamp work, can only be deposited in, or in the vicinity of, navigable waters, within limits to be prescribed for each case.‡

So jealously is this exclusive right of the Government regarded and exercised, that any alteration or modification of the natural capacity of any navigable waters, is forbidden without the previous authority of the Secretary of War, even though such alteration or modification might be for the absolute improvement of the waters.||

Any wreck, sunken vessel or cargo, which for the period of sixty days has been permitted by its owners to obstruct or endanger navigation, can be destroyed and removed by the Government, and the owner thereof will have no claim for damages arising from the destruction of such wreck, vessel or cargo. Should any parts of the vessel or cargo, after being removed, have any salable value, the amounts derived therefrom are turned into the treasury of the United States.§

The constructive works of improvement are guarded with as much care as the waters in which they are placed; and by the Acts of Congress it is made unlawful for any person to build upon, alter, injure, or in any manner impair, the usefulness of any sea-wall, bulkhead, jetty, dike, levee or other construction; or to remove or change any boundary mark, gauge, surveying station, buoy or other established marks of the United States.¶ Where the Government requires material for constructive purposes upon its public works, it may take such material from bars and islands, or

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* Acts of August 11, 1888; September 19, 1890.

† Acts of September 19, 1890; July 13, 1892.

‡ Act of August 5, 1886.

|| Acts of September 19, 1890; July 13, 1892.

§ Acts of June 14, 1880; August 2, 1882; September 19, 1890.

¶ Act of September 19, 1890.

other localities adjacent to such works, upon the payment of a fair compensation to the owners of such material.*

In the improvement of any navigable waters, the Government may close subsidiary channels, or in any manner considered necessary for accomplishing the desired improvement, divert the natural channel into new positions; and channels, or areas behind islands or bars, may be filled up. For any injury which may result to riparian owners from such diversion of the natural channel, or filling of channels and areas, there is no recourse at law; and his injuries, if any exist, belong to the class denominated "*damnum absque injuria*," or damage without responsibility. For any land or other property which may be required to carry into effect desired improvements, the Government can, if it desires, exercise the right of eminent domain, and so acquire title by condemnation proceedings.

This now declared and fully exercised right of the Government to conserve and control the navigable waters of the country, has been mainly brought about through the legislation of the last ten years; and, though so long delayed in its application, was nevertheless, all latent in that provision of the Constitution which gave Congress "the right to regulate commerce among the States." When we revert to the earlier position of the Government upon these questions, and note in the beginning its feeble application of inherent rights, the contrast between the past and present becomes very marked, and the progress toward absolute control very decided.

With the grand possibilities which are inherent in our waterways as a basis, with a policy so evidently directed to the full utilization of these possibilities, and with the best professional ability in the world to execute, there is every reason to anticipate that the near future will give this country a system of river and harbor improvements which will be the most extensive and complete in the world, and fully commensurate with our wonderful development along all other lines of national progress.

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* Acts of July 5, 1884; April 24, 1888.

There is another consideration connected with this subject that demands passing attention, and which has had and will continue to have, a strong bearing upon the question of river and harbor improvement. While these improvements have been in progress during the past thirty years, there has been a constantly-increasing demand for greater channel depths and widths, arising from the changes which have ensued in vessel building and the increased draft of such vessels. In 1858, when the (then) phenomenal *Great Eastern* was launched as the wonder of the world, she had a draft of twenty-five feet, and but one harbor in the United States, that of Portland, Me., had sufficient depth over its entrance bar at low tide to safely admit the giant. A few weeks ago many of my auditors may have witnessed the launch of the steamship *St. Louis*, with a loaded draft of twenty-seven feet, from Cramp's ship yards on the Delaware, and beyond passing notice and the feeling of justifiable pride over the success of Philadelphia's enterprising ship builders, the event was almost unnoticed.

Thirty years ago the dimensions and draft of ocean vessels was such that our great seaports of Boston, New York, Philadelphia, Baltimore, Norfolk, Charleston, Savannah and New Orleans, only required an entrance depth to their harbors of from eighteen to twenty-two feet at low water. To-day, ocean commerce demands depths in our channels and harbors of from thirty to thirty-five feet to meet the requirements of the modern ship's draft, and there is no reason to anticipate that the maximum requirements of channel and harbor depths have been reached.

The difficulties which confront the engineer, as well as the cost of the improvement, are increased far beyond the simple ratio of the increased requirements for the greater depths. Since in the past, our American engineers have so successfully met and overcome the obstacles of Nature in our great water highways, as well as the larger demands upon their skill arising from increasing requirements, so, in the future, we may feel assured that with enlarged experience and added resources they will ever stand well ahead of all demands upon their professional skill.

Time, and the proper limits of my subject, forbid any account of the works of river and harbor improvement which have already been accomplished by the application of moneys appropriated and the engineering skill which has been applied. Without invidious comparison with other and less prominent works, but which demanded no less care and skill, may be mentioned the improvements already accomplished in New York harbor by the removal of Gedney's channel bar and the rocky reefs at Hell Gate; the Delaware River, with the Breakwater at one end and Philadelphia harbor at the other, with a large number of intermediate points; the harbors of Baltimore, Savannah, Charleston, Mobile and Galveston; the rivers Hudson, Great Kanawa, Tennessee, Cumberland, Ohio, Mississippi, Missouri and Columbia, and the great works in the Sault Ste. Mary.

When a comparison is made between such works, and those undertaken or executed abroad by European engineers, we have every reason to turn with pride and satisfaction to our own results, and are justified in the claim that our own land not only furnishes many examples of the best modern practise and success, but equally, that our American engineers, if not already leaders, are at least the peers of their European brethren.

As population increases, better facilities must be furnished for water transportation; results already accomplished must be expanded, and still other new works of river and harbor improvement undertaken; and as new centres of population arise and expand, there must be a corresponding expansion of their commercial facilities. The possible demands of the future point toward a development of our present system of river and harbor improvement into something almost beyond suggestion.

Nationally, our development and progress have been so rapid in all directions as to be phenomenal, and so many evidences of this progress lie around us, that we naturally fail to note, except that which is nearest and which affects our personal environment. The subject which has been presented to you this evening may be one of the more

remote and obscured evidences of our progress, but, nevertheless, I feel assured that the rise and progress of river and harbor improvement is entitled to a place among the witnesses which are testifying to our national development.

THE NATURAL SODA DEPOSITS OF THE UNITED STATES.*

By Dr. Thos. M. Chatard.

The lecturer was introduced by Dr. Samuel P. Sadtler, Professor of Chemistry in the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Natural soda is the residue obtained by the evaporation of natural alkaline waters without the aid of artificial heat. It is composed of sodium carbonate and bicarbonate in varying proportions, mixed with impurities, mainly sodium chloride and sulphate. It is found to some extent in all dry regions, such as Hungary, Egypt and the deserts of Africa and Asia; but Nature has been especially bountiful to the United States in giving us a most valuable source of national wealth in the despised and detested "alkali dust" and "alkali water" of the Great Basin.

In its crude condition natural soda has been collected and utilized from the earliest times; but until its nature had been studied and proper methods of purification devised, the alkaline carbonates contained in it could not be obtained sufficiently pure and cheap to compete with the artificial product. Now that the technology of natural soda is fairly well understood, we may expect that the attention of capital will be drawn to the possibilities of this industry, the slender beginnings of which may be seen at a few places in the West.

The ancient Egyptians, who seem to have known every-

* A lecture delivered before the Franklin Institute, February 23, 1894.

thing that was knowable in their time, made much use of a substance which they called "neter."

The Bible describes "neter" as a solid substance, having cleansing properties, and as effervescing with vinegar. This was obtained from certain lakes and pools in the Egyptian deserts, and became at a very early date an important article of commerce.

The myth of the discovery of glass is interesting to relate at this point: Some Phœnician sailors, landing on a sandy shore, could find no stones large enough to support their cooking pots, and were compelled to use some lumps of the "neter" which formed a part of their cargo. The next morning they found that the heat of the fire had melted the "neter," which, fusing with the sand of the shore, had formed a glass. Of course, a true glass could hardly be formed in this way, as vitrification requires a high degree of heat, but the alkaline silicate thus produced is to-day used in large quantities and for many purposes.

The Greeks, becoming acquainted with this "neter," called it "nitron," and the Romans Latinized this to "nitrum." From the Latin is derived our English word "nitre," which we apply to an altogether different class of salts—the nitrates—and especially to the potassium nitrate, or saltpetre. Saltpetre, indeed, being a natural product and similar in appearance, was generally confounded with the true "nitrum" or crude natural alkaline carbonate, and the distinction between them appears first to have been made by the Arabs, who introduced the words "natron," "kali" or "alkali," and even "soda." From "natron" we get the word "natrona," and also the name "trona," usually given to the natural carbonate.

It must be remembered that, until the invention of gunpowder, there was no special demand for nitrates, while the need of cleansing materials, not only for domestic purposes, but also for the elaborate religious ceremonies of the ancients, made the preparation of some sort of soap a necessity of the earliest civilization. We need not be surprised to find that chemistry had its beginning in the collection, preparation and use of the "neter," or, as we now call it,

"natural soda." Moreover, the human race is supposed to have originated in Mesopotamia, while the earliest records of civilization are to be found among the Egyptians. Now, all these regions are arid in their climate and throughout their extent we find occurrences of natural soda. A knowledge of its properties and uses must have been early acquired, and must have accompanied the tribes in their subsequent wanderings. That wood ashes had similar properties would also be naturally discovered, and in time the value of the ashes of other plants, which of themselves are not especially valuable as fuel, would lead to the production of those crude alkaline carbonates which, under the names of "rocheta," "salicor," "varec," "kelp" and "barilla," have held their place in commerce almost down to the present day. The supply of such crude ashes is always uncertain, and their composition continually varies; hence, they have gradually been supplanted by the artificial alkalies, as these became purer and cheaper through the development of the Leblanc soda process.

We now come to an interesting case of the struggle for existence and survival of the fittest, exemplified by the history of the alkali trade. As our time is short, we cannot stop to consider the processes of artificial soda-making, further than to say that the great development of manufactures during the latter part of the last century, through the invention of machinery for spinning, weaving, etc., caused an enormous increase in the demand for alkalies, while at the same time the progress of civilization was tending to decrease the supply of the crude natural ashes. Under these conditions the price of crystal soda, which, at present, is about $15 a ton, was, in 1809, over $350; kelp, containing only three per cent. of soda, selling at the same time for $55 a ton (Lunge, Vol. II, p. 297).

These high prices stimulated chemical research, particularly as it was already well known, though no manufacturing process had yet been devised, that soda could be made from common salt. Much money and the time of many men were expended upon this problem. The glory of the successful solution of the problem, is due to the man who, as

Professor Lunge says, "is probably the most celebrated name in chemical technology"—NICHOLAS LEBLANC. On September 25, 1791, Leblanc obtained a patent in which his process is plainly set forth, and its essential features have remained unchanged up to the present time. These are: the treatment of common salt with sulphuric acid, producing Na_2SO_4 and HCl; in the fusion of the sulphate with coal and $CaCO_3$, producing black ash; the leaching of the black ash and the extraction of the alkali thus formed.

Leblanc was ruined by the French Revolution, and, becoming insane, committed suicide in 1806. The success of his process, however, had been established, and its operation steadily extended. A great increase in the chemical industry of Great Britain followed as the result of the abolition of the salt tax. In 1823, this tax amounted to the enormous rate of £30 or $150 per ton, but was then greatly reduced, and entirely abolished in 1825. England at once took the lead in chemical industry, which, in many departments, she has maintained until now.

Within the past twenty years, the ammonia-soda process, as developed by Solvay and others, has become a sharp competitor of the Leblanc process. In the ammonia-soda process, a strong solution of common salt is treated with ammonia and carbonic acid; sodium bi-carbonate is formed, and, being comparatively insoluble, precipitates and is filtered off. The ammonia is recovered from the filtrate, the whole of the chlorine of the salt being lost as calcium chloride. It is this loss that prevents this process from completely superseding all others. The Leblanc process only exists because it can utilize this chlorine, in the form of bleaching powder, chlorates, etc. As soon as the chlorine of the ammonia process can be recovered in an economical manner, the Leblanc process must disappear, and it seems that this must soon be accomplished.

But, in the moment of its triumph, the ammonia process is threatened with new and younger opponents. One is the electrolytic method of decomposing common salt; the other the natural soda, which is the subject of this evening's lecture. What, in the opinion of experts, is likely to be

the effect upon the alkali trade, of these new sources of production, can be shown by a quotation from a paper, by that eminent authority, Professor Lunge, of Zurich, entitled "The Progress of Chemical Industry in Europe in 1892," and published in "The Mineral Industry for 1892."

Speaking of the struggle between the Leblanc and ammonia-soda processes, and the reported success in utilizing the chlorine of the latter, he says:

"Supposing, however, that the Leblanc people are not to be killed by the blow threatening from that side, their doom is evidently sealed in another direction. After a long series of failures, some of the processes for making chlorine by electricity now seem to be securely established. We shall not discuss the question, which of them may be the best in the field; but it is certain that in some quarters all difficulties have been finally overcome, and that all other old or new chlorine processes will soon be out of favor. We poor Europeans may well tremble, as we think of the enormous advantages for all applications of electricity enjoyed by the United States, with their unbounded water-power, coal fields and oil wells, not to speak of natural gas. In all human probability, they will soon cease to be importers, and may even become exporters, of bleaching-powder.

"The electrical processes are certainly far greater sources of chlorine than of alkali. They produce from common salt, for every ton of bleaching-powder, only half a ton of soda ash, or one-third of a ton of caustic soda. The bulk of the alkali must, therefore, be supplied from other sources, undoubtedly at first in the form of ammonia-soda. But here, again, the mineral wealth of the United States is evidently destined to prove fatal to the old processes. There can be no doubt that the immense quantities of natural soda, shown to exist in the Californian and other soda lakes, will not be allowed to lie dormant any longer. If those lakes are once worked with the energy which is otherwise not wanting in America, the days are numbered when Liverpool soda will rule in the New York market."

Strong as this statement is, there is no reason to doubt

its correctness. When that day comes; when the natural soda of the United States shall have conquered a dominating position in the markets of this country, Nature will have avenged the defeat which she met with, when the barilla and kelp industries were killed by the art of man. The result will be far-reaching, and will work a complete revolution in chemical industry; for this, in great part, is based upon the manufacture of alkali, with its numerous ramifications, each having its special products. The salt, sulphur and ammonia trades will undergo important modifications, and, while some forms of industry may disappear, others will take their places.

The chemical industry of the United States, except in the line of drugs and fine chemicals, has not been developed, in volume or variety of products, to the extent warranted either by our natural resources, or by the ability and enterprise shown by the Americans in other branches of manufacture.

The large demand for sulphuric acid in the fertilizer and oil-refining trades, could, of course, be met by home production only, since transportation of such material from abroad is practically impossible. The sodium sulphate, obtained from the nitre-cake of the sulphuric acid works and from the salt-cake of the muriatic acid makers, is utilized for glass-making, most domestic attempts to convert it into alkali by the Leblanc method having apparently failed of commercial success. Almost all of our demands for alkali, and practically all of our needs for bleaching-powder, chlorates, and the other products of the Leblanc process, have been met by importation from abroad.

The Pennsylvania Salt Company has, by the use of cryolite, been an extensive manufacturer of soda for many years, while, about ten years ago, the Solvay Process Company established its works at Syracuse, N. Y., and has developed a large business. Other forms of the ammonia-soda processes are beginning, or preparing to begin, to share the field; and it is likely that before long the home demand for alkali can be met by ourselves, even if no use is made of the natural soda, of whose great future Professor Lunge speaks so decidedly.

Now, without trenching upon matters of private business, I can say that there is every prospect that before long arrangements will be perfected by which very extensive operations for the development of our natural soda will be started. If some former plans to this end have miscarried, it has not been because of any uncertainty as to the nature or extent of the supply, or because of any great technical difficulties in the manufacture of the market products. All of these matters have long since been settled, but capital is naturally conservative and is reluctant to enter upon new paths, particularly when the quantities to be dealt with are so enormous. The figures which I shall give you may sound almost extravagant, but be assured that they are much short of the truth; and now, without further delay, I shall give you some idea of a small part of our natural wealth.

From the remotest times of antiquity, the people of Egypt have used the salts gathered from a number of small lakes which are situated in the desert of St. Macarius, about sixty miles northwest from Cairo and about thirty-six miles from the Nile. According to Sickenberger, who lately examined this locality for the Egyptian Government, these lakes are sixteen in number, but only one is now worked for the salt. The surface of these lakes varies with the season, being lowest when the Nile is high, and highest when the river is low. This shows that the lakes are fed by the infiltration of the river water, which naturally takes a considerable time to pass over the intervening distance. The soil of the surrounding country is composed of alternating layers of limestone, ferriferous clay and calcareous sandstone; and in the clay are many crystals of gypsum and rock-salt, sometimes aggregated into layers. The water of the lakes contains sodium chloride, sulphate and carbonate in varying proportions; and, by spontaneous crystallization, a product is obtained which contains as much as sixty per cent. of sodium carbonate.

These lakes, being so long known, have frequently been visited and investigated by scientific travelers, and many hypotheses as to the mode of origin of the alkali have been

offered. Our time will only allow us to touch very briefly upon this matter; but a few words, at this point, will better enable us to appreciate the causes of the existence of our western alkali.

It must be understood that the soil around these lakes does not show the presence of alkali to any appreciable extent. Now, it has long been known that if a mixture of common salt (or sodium chloride), gypsum (or calcium sulphate) and limestone (or calcium carbonate) is moistened and exposed to the action of the air, the mass, which is at first neutral, soon begins to show an alkaline reaction on account of the formation of sodium carbonate, so that in time this new substance can be extracted from the mass by leaching. Until Sickenberger's visit, it had been supposed that the soda found in the lakes was formed in the soil in the manner just described, leached out by the water and thus conveyed to the lakes. He made the remarkable observation, however, that the water of the springs which feed the lakes is perfectly neutral, showing large amounts of sodium sulphate, but no carbonate. As soon, however, as the spring water reaches the surface and comes in contact with plant-life, the sulphate begins to decompose, giving off sulphuretted hydrogen, and being converted into sodium carbonate, the water becoming alkaline in reaction. As the lakes have no outlet, the inflowing water has no means of escape except by evaporation, leaving its salts behind; hence, the amount of carbonate in the lakes is continually increasing and the annual crops never fail.

While this is a very typical case of one mode of formation, there is another which is probably even more important. The existence of springs carrying sodium carbonate is well known, since many of them have a world-wide reputation for their medicinal qualities. Although most of them are weak solutions, a comparison of their compositions with those of the waters to be described will show that, by evaporation, they would yield a very pure natural soda. The sodium carbonate in such springs is produced by decomposition of the alkali-bearing rocks through which the water flows, and this decomposition is brought about by the combined action of

air and moisture, aided in many instances by heat and pressure.

The air absorbed by water contains a much larger proportion of oxygen and carbonic acid than the normal atmosphere. The composition of these dissolved gases may be taken as—

nitrogen, 79·00 per cent.; oxygen, 20·95 per cent.; carbonic acid, 0·04 per cent.,

while, according to Bunsen, the air absorbed by water at 15° C. (60° F.), contains—

nitrogen, 63·62 per cent.; oxygen, 34·12 per cent.; carbonic acid, 2·26 per cent.

The alkali-bearing minerals are generally silicates, having for bases ferrous or ferric oxide, alumina, lime, magnesia, soda and potash, in proportions varying according to the character of the mineral. By the action of water, containing CO_2, upon such minerals, the alkalies and alkaline-earths are converted into carbonates and dissolved in the carbonated water. Hence, they are leached out of the residue, which is rendered the more porous by the decomposition, and if the water so charged does not, on its way to the surface, meet with the chlorides or sulphates of other metals, which, by double decomposition, would produce alkaline chlorides, or sulphates, and non-alkaline carbonates, then the alkaline carbonates make their appearance as constituents of a mineral spring. In such springs the salts of sodium are usually in much greater proportion than those of potassium, not only because the soda minerals are in general more easily decomposable, but also because soils have a strong tendency to take up and retain potash salts from water percolating through them, while readily giving up any soda salts which they may contain.

If such spring or drainage waters flow into basins without outlet, and the rate of evaporation equals the inflow, a concentrated solution gradually results, and, if the inflow be interrupted, we shall, in time, have a dry basin in which the salts have deposited as a crystalline mass. It is evident that if the geological character of a country is favorable to the production of such alkaline waters, the dryness of the

climate, or the excess of evaporation over rainfall, determines the degree of concentration of the basins, the number and extent of which are dependent on the topography.

An arid climate is characteristic of many parts of the globe, hence there are numerous localities where pools and dry deposits of natural salts exist. The desert region of northern Africa, from Egypt to the Atlantic Ocean, the high plateaux of Armenia and Central Asia, the plains of Hungary and many portions of South America, abound in occurrences of these salts; while the lake of Tescuco, near the City of Mexico, has yielded natural alkali since long anterior to the time of Cortez. But all these sources of possible supply, taken together, sink into insignificance when compared with those of the United States, whether we consider their absolute magnitude and extent or their prospective importance.

In describing the localities within the boundaries of the United States, only the more important ones will be considered. Throughout the entire region which stretches from the Rocky Mountains to the Sierra Nevada, the climate is excessively dry, and only a small portion of the scanty annual rainfall finds its way to the sea. The rest either evaporates at once or drains into enclosed valleys. In the Great Basin, almost every valley has, in winter, its shallow lake of drainage water, which, in summer, more or less completely dries up, leaving behind a layer of salts. These are the "alkali flats," of which you have all heard, and which often stretch for miles, resembling new-fallen snow, and producing a glare well-nigh insupportable under that cloudless sky and burning sun. The arid soil of these plains supports a very scanty vegetation, and the winds drive before them dense clouds of dust heavily impregnated with "alkali," causing great annoyance to the traveler, even when he is a partaker of all of the advantages and luxuries furnished by Mr. Pullman. It may be well to note that in the West the term "alkali" means natural salts of every sort, which form upon the surface of the soil, or around the margins of pools. These salts are mostly mixtures of sodium salts, such as the chloride, sulphate and carbonate, and in

general it may be said that sulphate predominates on the eastern side of the region; chloride in the central portion, as in the Great Salt Lake; while the more valuable carbonate is found still further west, along the eastern slopes of the Sierra Nevada.

As seeing is believing, I will now ask you to accompany me on a trip from Omaha to San Francisco, *via* the Union Pacific Railroad, as the principal localities which yield natural soda can be reached by this line. Taking the Pacific Express at Omaha, in the evening, we reach Laramie, Wyo., twenty-four hours later. From Laramie a branch road runs nearly due south, thirteen miles, to the Soda Lakes, or, as they are usually called, the Union Pacific Lakes. Only one of these lakes usually contains water, the others, except in wet seasons, being dry deposits. The deposits are quite thick, being in some places 11 feet deep, and extend over hundreds of acres. The Downey Lakes, a few miles west, are similar in all respects and are equally extensive.

The salts in these lakes are sodium sulphate and chloride, the sulphate greatly predominating. The total amount of sulphate that can be obtained here is enormous, and it is often very free from other salts. As the Western demand for caustic soda is large, it was natural to suppose that it could be profitably made from this sulphate by the Leblanc process, particularly as the first stage of the process—the making of the sulphate—has already been performed by Nature. Repeated attempts have been made and much money has been spent to accomplish this, but so far without commercial success. The principal cause of failure is the large proportion of water in the sulphate. Its composition is that of Glauber's salts, or crystallized sodium sulphate, containing ten molecules of water of crystallization, or nearly fifty-six per cent. of the total weight. Before the sulphate can be converted into the "black ash" of the Leblanc process, this water must be got rid of—an operation which has proved so expensive as to destroy all reasonable expectation of profit. While the opinions of the best authorities hold out little hope that this sulphate can be profitably utilized in the near future, whoever can find

a satisfactory solution to the problem must reap a rich reward.

On the line of the Union Pacific Railroad, and 136 miles west of Laramie, is Rawlins; and 50 miles north of Rawlins lies the Sweetwater Valley, in which are the Dupont Lakes. These are four in number and differ from the Laramie Lakes in containing a considerable proportion of sodium carbonate. For this reason, and because coal and limestone are reported to exist near-by and in ample supply, a flourishing industry may here be built up whenever the transportation facilities have been developed. Continuing along the road from Rawlins, we see many patches of alkali, which, however, contains little or no carbonate, and, passing through the beautiful Echo Cañon, we reach the Great Salt Lake. This is a dense solution of common salt with much sulphate. In winter the latter crystallizes out in large quantities along the shore, and some attempts have been made to utilize it, but, so far as I have heard, the results have not been favorable.

From Great Salt Lake, another day's journey, during which we observe an increasing number of alkali flats, brings us to Wadsworth, Nevada. From this point we proceed by wagon southward toward the sink of the Carson River. The entire journey is through a very arid region, the latter portion being a sandy waste on which even sage brush can hardly grow. After twenty miles of a terribly hot journey, we reach a place called Ragtown, consisting of a house and a well. I do not know much about the house, but the well is good.

Ragtown, though now deserted, has a history, and was a place of much importance before the advent of the transcontinental railway. It was the long and greatly desired goal of the emigrant, who, having painfully toiled through the deserts of Utah and Nevada, could, when he beheld the tents of Ragtown and the green banks of the Carson, at last feel sure that the danger of death, by starvation and thirst, was over. Tired and ragged, with worn-out cattle, he there met traders from California, from whom he could obtain fresh oxen and fresh clothes. Poor as the emigrant's cattle

might be, they still had some value in barter, since, after recuperating in the valley of the Carson, they could be sold to later arrivals; but no one wanted the old clothes, so these were cast to the winds, and by their picturesque plenty and confusion gave to the great emporium the euphonious name of Ragtown. Its inhabitants, its glory, even its rags, have departed. Its name would perish were it not for the remarkable natural occurrences which exist near-by, and which are known as the Big and Little Soda Lakes.

[*To be concluded*]

A REMARKABLE ELECTROLYTIC PHENOMENON.*

By C. J. Reed.

Most metals, when used as positive electrodes in electrolysis, are either dissolved or corroded, producing metallic salts or oxides; but when used as negative electrodes, metals do not generally undergo such corrosion. They are seldom affected in any way, chemically, by the action of the current, and are never dissolved.

It is to what appears to be an exception to this rule, that I wish to call your attention this evening.

While experimenting, some time ago, on the oxidizing effect of various electrolytes upon lead electrodes, I noticed, accidentally, that under certain circumstances, lead behaves toward some electrolytes in a very peculiar manner. The only conditions required are that the electromotive force and current density shall be very high.

On passing an electric current through a solution of disodium-hydrogen phosphate, between electrodes of sheet lead, I noticed nothing unusual during the experiment. The solution had a very high resistance and very little current passed even with a high electromotive force. At the close of the experiment, there being no switch in the circuit, the current was interrupted by lifting one of the elec-

* Read at the stated meeting of the Electrical Section, February 27, 1895.

trodes out of the solution. It happened to be the negative electrode.

At the instant of final contact between the electrolyte and the lowest point of the electrode, as it left the solution, I noticed what appeared to be a cloud of black smoke, or precipitate, which had suddenly formed in the solution. On examining the cloud more particularly, and repeating the experiment several times, I found that by exposing only a very small surface of the negative electrode to the solution, there was produced a voluminous cloud of dark blue or lead-colored precipitate, which rapidly sank in the solution and rendered it entirely opaque.

It was then observed that the lead cathode was being rapidly eaten away, and that the precipitate was being produced at the expense of the lead. The precipitate was collected on a filter, washed with water and alcohol, and dried. It was found to be an impalpable powder resembling lead, and permanent in the air at ordinary temperatures. When rubbed in an agate mortar, it was reduced to a lustreless gummy mass, but did not assume a metallic appearance. Heated to the melting point of lead in the open air, it suddenly absorbed oxygen and formed yellow plumbic oxide, with incandescence. Heated in a glass tube in absence of oxygen, it melted to a globule of metallic lead.

In this bottle I show you a sample of this product that has been preserved more than two years without any apparent change.

The surface of the lead cathode, after the experiment, exhibited a peculiar appearance. It was reduced to a point at the end, and presented a smooth, shiny surface, like polished lead. It was of the form we should expect to find a positive electrode of copper or other soluble metal.

Other electrolytes were tried and it was found that the lead precipitate could be produced in the following solutions :

Potassic sulphate,
" hydric sulphate,
Sodium orthophosphate,
Di-sodic-hydric phosphate,
Sodic-di-hydric phosphate,
Magnesic sulphate,
Calcic sulphate,
Aluminic sulphate,
Ammonic oxalate,
Sodium hypophosphite,
" sulphide,
" thiosulphate,
" sulphite,
" chloride,
Potassic chlorate.
Potassium sulphocyanide,
" ferrocyanide,
" ferricyanide,
" iodide,
" bromide,
" carbonate.
Calcic chloride (with difficulty),
Strontium sulphate,
Manganous chloride,
Sodium borate,
Potassium acetate,
Ammonium hydrate,
Hydric phosphate,
Ammonic sulphide,

The precipitate could not be produced in solutions of the following substances:

Barium hydrate,
" chloride,
Calcium hydrate,
Ammonium carbonate,
Strontium nitrate,
" chloride,
Hydric sulphate,
Hydric acetate,
" oxalate,
Ammonic acetate,
" nitrate,
" chloride,
Potassium bi-chromate,
" nitrate.

The precipitate could not be formed in solutions of metallic salts from which a metal can be deposited by electrolysis. It cannot be formed in strong acids having a great affinity for lead.

With ammonium oxalate and a positive electrode of platinum, there was formed on the platinum wire what appeared to be a deposit of lead peroxide, although no lead was originally in the solution. In a recent experiment I failed to produce this result.

Similar experiments were made with negative electrodes of iron, zinc, cobalt, nickel, manganese, magnesium, aluminium, copper, cadmium, silver, gold, platinum, bismuth, arsenic, antimony and tin. Of these, arsenic alone acted in a manner somewhat similar to lead, being rapidly disintegrated as a negative electrode. The surface of the metal where the action took place was smooth, bright and rounded, apparently polished. A film of brown, solid arsenic hydride

was formed, which, instead of sinking, floated away from the electrode in straight lines on the surface of the solution. This hydride was also produced electrolytically by Sir Humphrey Davy.

With lead electrodes, in a solution of sodium phosphate, some hydrogen phosphide was produced along with the lead precipitate.

With borax and lead electrodes, the lead precipitate was formed very rapidly; and when the negative electrode was held close to the side of the glass beaker, a bright reddish-brown stratum of liquid was seen to be continually formed at the surface of the electrode. This disappeared almost instantly after moving away from the electrode, but was continually formed as long as the current was strong enough to produce the lead precipitate. The addition of acetic acid did not prevent this formation.

Sodium thiosulphate gave a deposit of sulphur at the positive pole, confirming the theory that in the thiosulphates one atom of sulphur is electro-negative, and takes the place of an atom of oxygen in the sulphates.

With sodium sulphite, sulphur dioxide was liberated at the positive plate.

Strontium nitrate, instead of giving the lead powder, gave a blue flame around the point of the lead cathode.

These results seem to indicate the possibility of obtaining, by the use of high electromotive force and high current density in electrolysis, products of an entirely different nature from those of ordinary electrolysis.

A METHOD FOR DETERMINING SULPHUR IN ROASTED SULPHIDE ORES.*

By Harry F. Keller and Philip Maas.

Numerous methods have been proposed for the estimation of sulphur in materials containing it in the form of sulphides not decomposable by hydrochloric acid. New methods, as well as modifications of older ones, are contin-

* Read at the stated meeting of the Chemical Section, held January 18, 1895.

ually devised; analysts do not seem satisfied with the existing processes, and it must be admitted that a method which is both accurate and expeditious, still remains a desideratum.

The great majority of methods now practiced consist in oxidizing—either in the dry way or wet way—the sulphur to sulphuric acid, and estimating the latter gravimetrically or by titration.

The method we are about to describe is likewise based on this principle, and is a combination of well-known reactions. What we claim for it is that it is specially adapted for the determination of the sulphur in roasted copper ores and cupriferous pyrites.

The conversion of the sulphur into an alkaline sulphate is effected by fusion with potassium hydrate and sodium peroxide, and the amount of sulphur is then ascertained in the usual manner—gravimetrically, when accuracy is the principal object—by the Wildenstein method, when rapidity is aimed at.

The details of the process are as follows: Five to six grams of caustic potash (pure by alcohol) are fused in a nickel crucible and heated until the excess of water is expelled. The size of the flame is now reduced so that the contents of the crucible just remain liquid, and ·5 grams of the finely powdered material introduced in small portions. A gram of sodium peroxide is then added while the heat is gradually increased to redness, and this is maintained for a few minutes. After cooling, the fused mass is dissolved in water, and the solution filtered with the aid of a pump. The undissolved residue is washed four or five times with hot water.

The colorless * filtrate is acidified with hydrochloric acid (8–9 c.c., sp. g. 1·2) and boiled to expel carbonic acid.

If the estimation is to be made gravimetrically, the sulphate of barium is precipitated from the boiling liquid in the usual manner. In case, however, titration is resorted to, the liquid is made alkaline with ammonia (about five c.c.,

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* Before filtering the liquid is often colored purple by a small amount of ferrate of potassium; a blue color in the filtrate indicates that too much potash was used.

sp. g. ·9). A slight excess of standard barium chloride solution is added from a burette, and the excess measured with an equivalent solution of dichromate of potassium. A distinct yellow color of the liquid marks the end of the reaction. After a little practice it is generally easy to strike this point, though it will sometimes happen that the precipitate does not settle rapidly. In such doubtful cases, portions of the liquid should be filtered off. Care should also be taken that the liquid does not become too dilute. It is convenient to prepare the standard solutions of such strength that one c.c. is equivalent to ·005 grams of sulphur, *i. e.*, indicates one per cent. in a sample weighing ·5 grams.

The solution of barium chloride is prepared by dissolving 38·109 grams of the crystallized salt to a liter, while the dichromate solution should contain 23 grams of the salt per liter.

To test the accuracy of our method, a considerable number of determinations were made of the sulphur in a typical roasted copper ore from Montana.

By oxidation with nitric acid and with aqua regia the percentage of sulphur in this material had been found to be 7·095 and 7·14, respectively.

Somewhat lower results were obtained by fusion with caustic potash and potassium chlorate, a method which had been used by one of us to control the working of a lead ore roasting furnace. The figures varied from 6·78 per cent. to 6·92 per cent.

Our first attempts to oxidize the ore by means of sodium peroxide were not successful. By using 10 grams of potash and 3–5 grams of peroxide, figures much lower than those before given resulted.

The oxidation was evidently incomplete. When bromine water was added to the solution of the fused mass, 6·82 per cent. of sulphur was obtained.

To our surprise a higher percentage was also found when less of the peroxide was employed. Thus with 10 grams of potash and 1 gram of peroxide the determinations averaged 6·8 per cent.

The large excess of alkali employed in these fusions in-

variably caused the solution of some copper, which renders titration impossible. Our next step, therefore, was to reduce the amount of potash.

When 5 grams of hydrate and 1 gram of peroxide were taken, the filtered solution of the fused mass was entirely free from the blue tint produced by the copper, and it is seen from the following figures that the oxidation of the sulphur was complete:

(1)	6·71	per cent. S.
(2)	6·82	" "
(3)	6·79	" "
Average	6·77	" "

Volumetric estimations gave the following results:

(1)	6·74	per cent. S.
(2)	6·86	" "
(3)	6·89	" "
(4)	7·14	" "
(5)	6·97	" "
Average	6·92	" "

Another series of determinations, in which a preparation of potash marked *puriss pro analys.** was used, yielded:

(1)	6·70	per cent. S.
(2)	7·09	" "
(3)	6·71	" "
(4)	6·85	" "
(5)	6·79	" "
(6)	7·00	" "
Average	6·85	" "

A final series in which the directions given in this paper were strictly adhered to, resulted as follows:

(1)	6·90	per cent. S.
(2)	6·75	" "
(3)	7·15	" "
(4)	7·05	" "
(5)	7·05	" "
(6)	7·10	" "
(7)	7·14	" "
Average	7·05	" "

The time required for the volumetric assay does not exceed thirty minutes.

*A correction of ·35 per cent. was necessary in this case, the potash being less free from sulphur than that labelled "pure by alcohol."

The ATOMIC WEIGHT of TUNGSTEN.*

By Edgar F. Smith and Enric D. Desi.

When we examine Clarke's Recalculations of the Atomic Weights, or Becker's Atomic Weight Determinations, we will find various figures representing the atomic mass of tungsten, which differ greatly from each other.

The method pursued by most of the experimenters was the reduction of tungstic acid and weighing of the reduced metallic tungsten; some oxidized the metal to tungstic acid, and Bernouilli also reduced the trioxide of tungsten and calculated the atomic weight from the amount of water formed.

The cause of these great differences is due not so much to the methods employed as to the impurities contained in the material used for the experiments. All have recognized this, and their principal aim was to obtain a chemically pure tungstic acid. It is comparatively easy to rid the substance from iron, manganese, aluminum, etc. But some difficulty is encountered in removing the last traces of silicic acid, and in separating molybdenum, which was not eliminated in most determinations. The analogy of the compounds of these two metals makes their separation more difficult, and the importance of the influence of the presence of molybdic acid (MoO_3) upon the results of the atomic weight determination of tungsten was recognized by Schneider (*Journal für praktische Chemie*, **50**). He took the greatest pains in preparing a pure material, and removed the molybdic acid by strong ignition. Later investigators, however, have shown that it is not possible to completely separate tungsten from molybdenum by mere ignition.

Waddell more recently (*American Chemical Journal*, **8**, 280), after considerable and careful work, obtained probably purer material than previous investigators. He found many difficulties in separating molybdenum from tungsten, and con-

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* Read before the Chemical Section, January 18, 1895.

sidered Rose's method of separation as the most convenient; but Traube (*Jahrbuch für Mineralogie*, etc. *Beilageband*, *VII.*, p. 232), and more recently Friedheim and Meyer (*Zeitschrift für anorganische Chemie*, **1**, 76), have shown that by Rose's method the elimination of molybdenum is not complete.

It is safe to admit that all former investigators had a tungstic acid contaminated with more or less molybdic acid, which tended to lower the atomic weight of tungsten, and the proof of it is the latest work on this subject by Pennington and Smith (*Proc. Amer. Philos. Soc.*, **33**, 332), who obtained a value (184·90), that differs quite appreciably from that usually accepted as representing the atomic mass of the element under consideration.

We have undertaken, in this present investigation, to determine the atomic weight of tungsten from the quantity of water formed by the reduction of tungsten trioxide. Bernouilli (*Poggendorf's Annalen*, **111**, 599) attempted to determine this constant in the same way, but the value which he obtained (186) we must consider as too high.

The greatest care was taken to obtain a really chemically pure tungstic acid, for the purpose of ascertaining whether the elimination of the last traces of molybdenum would be likely to produce a rise in the atomic mass.

We obtained our tungstic trioxide by digesting the finely-powdered mineral wolframite from Zinnwald (Bohemia), in aqua regia, for several days; the trioxide thus obtained was boiled in a porcelain dish for five days in aqua regia, decanting from time to time the exhausted acid, washing the yellow oxide thoroughly with water. This operation was continued until the acid and washings showed complete absence of iron. The well-washed trioxide was then brought in a porcelain dish, covered with water, and ammonia-gas conducted into the liquid until saturated, dissolving the tungstic acid to ammonium metatungstate [$W_4O_{13}(NH_4)_2 + 8H_2O$.] Several days were required for this operation, and only a little greenish residue remained undissolved, containing traces of iron and probably columbic acid. The clear ammoniacal solution, after filtration, was concentrated in a porcelain dish almost to the point of crystallization. During

this operation it was necessary to filter several times, an amorphous brown precipitate being formed, as well as a gelatinous one, probably traces of silica. The concentrated solution was left standing to crystallize out the metatungstate of ammonium. The white crystalline needles were thoroughly washed with water, dried and ignited in a porcelain crucible to tungstic acid, excluding the entrance of dust by a large, suspended porcelain cover, admitting the air freely. This tungsten trioxide was twice re-crystallized and ignited and finally digested with yellow ammonium sulphide, excluding the air as much as possible, heating gently until the solution had a reddish-brown color. A little black residue was filtered off and tungsten trisulphide (WS_3) was precipitated from the clear solution of ammonium sulphotungstate [$WS_4(NH_4)_2$], by additions of small quantities of pure hydrochloric acid. After washing the precipitate by decantation and on the filter, it was dried and ignited in an open porcelain crucible to tungstic acid. After boiling this tungstic acid for two days in aqua regia, frequently renewing the acid and washing thoroughly with water, the trioxide was dissolved once more in yellow ammonium sulphide, no residue whatever being left behind. This solution was treated as above and the resulting tungstic sulphide ignited to the trioxide.

So far, we were perfectly sure that we had no iron, manganese, aluminum, silica, etc., contaminating our tungstic acid.

Now one more element remained to be separated from tungsten, and this is molybdenum. The presence of molybdenum was proved by converting a small quantity of the purified trioxide into the ammonium salt, and applying the sulphocyanide test, Braun (*Zeitschrift für analytische Chemie*, **2**, 36), which showed plainly the presence of this element. This demonstrated that the many previous operations of purification did not eliminate molybdenum, and strengthens our opinion that the tungstic trioxide used in all former investigations, except that of Pennington and Smith (*loc. cit*), was contaminated with molybdenum. To separate these two elements we had recourse to the vola-

tility of molybdenum oxychloride (MoO_3 2HCl) Debray (*Comptes Rendus*, **46**, 1098, 1850) (*Liebig's Annalen*, **108**, 250).

The experiments of Pechard (*Comptes Rendus*, **114**, 173, and *Zeitschrift für anorg. Chemie*, **1**, 262), and those more recently made by Smith and Oberholtzer (*Jour. Amer. Chem. Soc.*, **15**, 18, and *Zeitschr. für anorg. Chemie*, **4**, 236), and by Smith and Maas (*Jour. Amer. Chem. Soc.*, **15**, 397, and *Zeitschr. für anorg. Chemie*, **5**, 280), prove beyond doubt the quantitative separation of molybdenum from tungsten by heating and passing dry hydrochloric acid gas over the mixture, the following reaction taking place:

$$MoO_3 + 2HCl = MoO_3\ 2HCl.$$

Small portions of the purified tungstic acid were placed in porcelain boats and exposed to the action of pure hydrochloric acid gas, prepared from salt and pure sulphuric acid. The gas escaping from the generating flask passed through a bottle with sulphuric acid and a tower filled with calcium chloride, and then entered the combustion tube, where it came in contact with the tungsten trioxide. A gentle heat was applied and gradually increased to about 200° C., until the white volatile sublimate of molybdenum oxychloride was no longer observed. The residue in the boat always showed some traces of reduction, so that it was re-oxidized in open porcelain crucibles. To determine complete absence of molybdenum small portions of it were subjected to the sulphocyanide test; no trace of the molybdic reaction was observed.

Only now we considered that we had a chemically pure tungstic acid, and proceeded to the actual determination of the atomic weight. This was done by conducting a current of pure and dry hydrogen over a carefully-weighed quantity of tungstic acid, collecting the water formed in a U-tube filled with freshly calcined calcium chloride.

The hydrogen used by us in the reductions was prepared from pure sulphuric acid and the purest obtainable zinc. To purify the gas it was conducted through a series of bottles containing potassium permanganate, an alkaline solution of

lead nitrate, silver nitrate, sulphuric acid, caustic potash, calcium chloride, and finally through a nine-inches-long glass tube, filled with bright, polished iron wire, the latter being gently heated. After this, the gas was admitted to the tube, where it came in contact with the ignited tungstic acid contained in a platinum boat. The water produced in the reduction was collected in a weighed, glass-stoppered U-tube, filled with anhydrous calcium chloride. A similar tube was attached to this, to prevent absorption of moisture from the surrounding atmosphere. Before beginning the reduction, the tube was dried thoroughly, until constant weight of the U-tube was obtained.

The reduction of tungstic acid is not very easy, requiring a very high temperature and long time; in our experiments we ignited for about eight hours. After displacing the hydrogen in the U-tube, it was hung in the balance-case for half an hour, and then weighed; a second weighing was made after twenty minutes, but no difference was observed. The balance and the weights were perfectly adjusted, and all weighings reduced to the vacuum standard, and in the calculations, oxygen was taken as 16 and hydrogen as 1·008 (Clarke).

The results of six experiments were as follows:

	Weight of Tungstic Acid in grams.	*Weight of Water in grams.*	*Atomic Mass of Tungsten.*
(1)	0·983024	0·22834	184·683
(2)	0·998424	0 23189	184·709
(3)	1·008074	0·23409	184·749
(4)	0·911974	0·21184	184 678
(5)	0·997974	0·23179	184·704
(6)	1·007024	0 23389	184·706

Mean,	184·704
Maximum,	184·749
Minimum,	184·678
Difference,	·071

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The REDUCTION of ALUMINA CONSIDERED FROM A THERMO-CHEMICAL STANDPOINT.*

By Joseph W. Richards, A.C., Ph.D.

The writer is a firm believer in the usefulness of thermochemical data as a guide in chemical experiment. However, the deductions drawn from these data are often incorrect, because all the conditions have not been taken into account. Berthelot has postulated the "law of maximum work," which affirms that every chemical reaction takes place with the maximum production of heat possible by the combination of the reacting substances. This law, however, is too limited; it leaves out of consideration altogether the disturbing effect of the relative masses of the substances, their physical condition and the physical condition of the products. For instance, an excess of a reducing agent is often necessary to reduce an oxide, producing or causing to take place a highly endothermic reaction. Again, if one of the possible products of a reaction would be in such a physical condition as to be quickly and completely removed from the sphere of the reacting bodies, its formation will be greatly accelerated. If two solutions are mixed and one of the possible products of their reaction is insoluble in the solution, this fact will determine the formation of that substance, even though the reaction is an endothermic one. The heat deficit will simply be made up by an abstraction of heat from the solution; it will be cooled. Similarly, if two solids or liquids, or a solid and a liquid, are brought into intimate contact, and the possible result of their reaction should be a gas, the reaction will tend to take place, even if endothermic, because the gas escapes from the field of reaction as soon as produced, and so the inverse reaction is prevented. In such a case, putting pressure on the substances would hinder the formation of gas and retard the

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reaction; removing the pressure would facilitate the reaction. It has been proved, experimentally, that mercuric oxide and carbon react at a lower temperature when warmed in a vacuum than when at ordinary pressure.

Another important point is, that there is, under a given pressure, a critical point of temperature at which reactions first take place, the explanation of which is that the particles of the original substances are themselves bound together by chemical affinity, and that the molecular vibration corresponding to a certain temperature is necessary before the new affinities tending to produce the reaction can overcome the original affinities of the primary substances. At 555° C. the atoms of oxygen and hydrogen, in the molecules of their respective gases, are vibrating to such distances from their mutual centre of attraction, that the new affinity of the unlike atoms for each other is able to disrupt the original molecules, and combination occurs. Similarly, carbonic oxide can break up the oxygen molecule only at 655° C. These remarks apply to the free gases at ordinary pressure. Under other conditions, the oxidation can go on at different temperatures.

If the substances are brought to the critical temperature at which they react, and the reaction at that temperature is exothermic, then the exchange will take place and proceed of itself until complete. If the reaction is endothermic, the first reacting portions absorb heat from the rest and lower the temperature below the critical point, thus putting a stop to the reaction, the exchange starts again only when the temperature is kept up to the critical point by the liberal supply of heat from without. This is the *modus operandi* of the reduction of many strong oxides.

The heat of formation of a molecular weight of alumina (102 parts) was determined by Baille and Féry, by oxidizing aluminium amalgam. The reaction is

$$Al^2Hg^3 + 3O = Al^2O^3 + 3Hg = + 392{,}600 \text{ calories.}$$

This is evidently the heat of oxidation of liquid aluminium to solid alumina, *minus* the heat of formation of Al^2Hg^3. This latter quantity is unknown, but is probably quite

small. These investigators determined the heat of hydration of alumina; thus

$$Al^2O^3 + 3H^2O = 2Al(OH)^3 + 3,000 \text{ calories.}$$

Berthelot, long previously, had found the heat of formation of hydrated alumina to be 391,600 calories. This would give 388,600 for anhydrous alumina, but this figure is based on the oxidation of *solid* aluminium. To compare it with Baille and Féry's figures, we must *add* to it the latent heat of aluminium at 0° C., which is calculated as follows:

		Calories.
Latent heat of 1 kilo aluminium at the melting point		100·0
Heat given out by 1 kilo of molten aluminium in falling from 625° to 0° = 625 × 0·308 (sp. heat molten aluminium), determined by Pionchon	*Cal.* 192·5	
Heat given out by 1 kilo of solid aluminium through the same range (writer's experiments)	158·3	
Decrease in the latent heat		34·2
Latent heat of 1 kilo at 0° C.		65·8
The latent heat of 54 kilos (Al^2) is, therefore, ...		3550·0

Adding this to Berthelot's corrected value for anhydrous alumina from solid aluminium, the sum is 392,150 calories. This agrees so closely with Baille and Féry's figures that the latter are accepted as being very near the truth.

Concerning the reduction of this compound to metallic aluminium, two ways are possible—the direct and the indirect. By the first I mean the use of an agent which is powerful enough to reduce it to metal at a single step; by the indirect is meant, first, reducing alumina to a more tractable aluminium compound, and then reducing the latter. Leaving electricity entirely out of consideration, there are but very few reducing agents which can decompose alumina directly, and they only at very high temperatures. Sodium does not act on it at any temperature, since sodium oxide is a far weaker compound than alumina.

$$3Na^2 + 3O = 3Na^2O + 299,280 \text{ calories.}$$

If the alumina, however, is converted into an oxygen-free aluminium salt, its affinities are then much weaker, while the reducing power of sodium is relatively much greater.

Chlorine and carbon together decompose alumina,

$$Al^2O^3 + C + 6Cl = 2AlCl^3 + 3CO$$

Heat absorbed:

Decomposing alumina		392,600

Heat liberated:

Aluminium chloride	325,510	
Carbonic oxide	88,200	
		413,710
Excess of heat		21,110

This reaction proceeds easily at a bright red heat; in fact, we not only have an exothermic reaction, but the products also are all gaseous, and as soon as the critical temperature at which the reaction begins is reached, the operation proceeds rapidly and completely.

The aluminium chloride is easily reduced by sodium, potassium, lithium and magnesium, perhaps to a slight degree by manganese and zinc, which have about an equal affinity for chlorine. No other substances, organic or inorganic, besides these few rare alkaline and alkaline-earth metals, have a heat of combination with chlorine sufficient to decompose aluminium chloride.

Bromine and iodine vapors do not act like chlorine, and the reason is seen in casting up the thermal data. The difference between the heat of formation of alumina and three molecules of carbonic oxide is 392,600 — 88,200 = 304,400 calories. Against this, chlorine formed aluminium chloride and gave 325,510 calories, making the reaction exothermic by 21,110 calories. Bromine, however, in forming the bromide, gives only 243,550 calories, leaving a deficit of 60,850 calories, while iodine gives only 144,310, leaving a deficit of 160,190 calories. The only known way of making these compounds is directly from aluminium itself.

Sulphur, also, is unable either alone, or with the assistance of carbon, to split up alumina. The heat of formation of aluminium sulphide being 127,950 (from liquid aluminium), the enormous deficit of 304,400 — 127,950 = 176,450 calories, makes the reaction impracticable. However, when carbon bisulphide vapor is passed over white-hot alumina, alu-

minium sulphide is formed. It would appear at first sight as if the compound of carbon and sulphur would be less likely to produce the reaction than those elements uncombined; but the secret of this paradox is disclosed when we note that carbon bisulphide is one of the few endothermic compounds, absorbing 29,000 calories in its formation, and giving out just that amount in its decomposition. This helps to reduce the deficit by just so much. Further, carbonic oxide is not formed, but carbonyl sulphide, which has a heat of formation 4,700 calories higher for each atom of oxygen taken up. Casting up the thermal data, we have

$$Al^2O^3 + 3CS^2 = Al^2S^3 + 3COS.$$

Heat absorbed:

		Calories.
Decomposing alumina		392,600

Heat evolved:

Formation of aluminium sulphide	127,950	
" " carbonyl sulphide	102,300	
Decomposition of carbon bisulphide	87,000	
		317,250
Heat deficit		75,350

This is still a large deficiency, but the critical temperature for the reaction is a white heat, and, if the supply of carbon bisulphide is abundant and the heating is kept up energetically, the reaction is practicable.

As for reducing this sulphide to metal, thermal data show us that only the alkaline and alkaline-earth metals can accomplish it easily, while manganese, zinc, tin, iron and copper can do it to a small extent when used in large excess, making use of the influence of mass to bring about the endothermic reaction. This compound recommends itself more particularly for electrolytic decomposition. When mixed with an alkaline sulphide it forms an easily fusible double sulphide, which theoretically requires less than one volt to decompose it.

Alumina is easily converted into its fluoride, which, however, can only be decomposed chemically by the alkaline or

alkaline-earth metals. Even fluorine alone acts energetically on it, raising it to incandescence.

The reaction

$$Al^2O^3 + 6F = 2AlF^3 + 3O$$

sets free 555,550 — 392,600 = 162,950 calories, which accounts for the phenomena observed.

Even hydrofluoric acid gas can be used for the reaction, the splitting up of six molecules of gaseous hydrofluoric acid requiring, at 0° C., 222,600 calories, against which we have the formation of three molecules of water, 174,300 calories, leaving for the reaction a net excess of

$$Al^2O^3 + 6HF = 2AlF^3 + 3H^2O + 114,650 \text{ calories.}$$

A reaction similar to this is impracticable with hydrochloric acid gas, and we find that it would be endothermic to the extent of about 30,000 calories.

DIRECT REDUCTION.

Minet has measured carefully the voltage required to decompose alumina dissolved in a fluoride bath, using a carbon anode, at which carbonic oxide is formed. As one volt represents a thermal value of 23,000 calories for each equivalent of oxygen liberated, it would represent 23,000 × 6 = 138,000 calories for each molecule of alumina split up. The number of calories represents, therefore, the thermal value of the following reaction:

$$Al^2O^3 + 3C = Al^2 + 3CO$$

at the temperatures given. Minet's best experiments gave:

Temperature.	*Voltage.*	*Calorific Equivalent* (3O.]
900°	2·40	331,000
1100°	2·17	299,460

If we can add to these numbers the heat evolved by the reaction $3C + 3O = 3CO$, at these temperatures, we shall obtain the value of the reaction $Al^2 + O^3$, or the heat of oxidation of liquid aluminium to liquid alumina. This calculation is made as follows:

$$C + O = CO + 29,400 \text{ calories at } 0° \text{ (Berthelot).}$$

Specific heat of carbon ($t > 900°$) . . . . $0.53 \times \frac{134.6}{t}$ (a)
(Pionchon.)

Specific heat of oxygen . . . . $0.2114 + 0.00001875t$ (b)
(LeChatelier and Mallard.)

Specific heat of carbonic oxide . . . . . $0.245 + 0.0006t$ (c)
(Regnault.)

Therefore,

$$C + O \left(\begin{matrix} \text{at } t° \\ t > 900° \end{matrix} \right) = 29{,}400 + (12a + 16b - 28c)t.$$
$$= 27{,}785 + 2.8824t - 0.0003t^2.$$

Substituting, we have

At 900°, $C + O = 30{,}136$ $3(C + O) = 99{,}408$
At 1100°, $C + O = 30{,}592$ $3(C + O) = 91{,}776$

Adding these to the values of the reaction given by Minet's experiments, we have

At 900° $Al^2 + O^3 = 331{,}000 + 90{,}408 = 421{,}408$ cal.
At 1100° $Al^2 + O^3 = 299{,}460 + 91{,}776 = 391{,}236$ cal.

Now, we know that at 0°, $Al^2 + O^3 = 391{,}600$ calories, the only difference between this and the figures just derived being that the latter is calculated for *solid* alumina. For liquid alumina, we should have to subtract from it the latent heat of fusion of alumina. This is not known, but if we estimate it at forty-three calories per kilo (from analogy with other oxides), we may subtract $43 \times 102 = 4{,}400$ calories. We then have the heat of formation of liquid alumina from liquid aluminium, as follows;

	Calories.
0°	387,200
900°	421,408
1100°	391,236

It will be noticed that the value has reached a maximum between 0° and 900°, and is rapidly decreasing; in other words, above 1,000° alumina rapidly becomes easier to decompose. A curve passing through the above values would be of the following form:

$$Q = 387{,}200 + 192.6t - 0.1716t^2.$$

The question now is: "At what temperature would the heat of oxidation of our reducing agents equal the heat of formation of alumina? We may fairly assume that if that

point is above the critical point for the reaction, reduction will there begin.

Carbon.--The formula for the heat of oxidation of carbon to carbonic oxide has already been deduced. We therefore have

$$Al^2 + O^3 = 387{,}200 + 192{\cdot}6t - 0{\cdot}1716t^2$$
$$3(C + O) = 83{,}355 + 8{\cdot}6472t - 0{\cdot}0009t^2$$

When these two expressions become equal to each other

$$t = \underline{\underline{1980°}}$$

If liquid carbon is the reducing agent, its efficacy is about 21,000 calories greater than solid carbon, and

$$t = \underline{\underline{1940°}}$$

As verifying these calculations, I may refer to the fact that liquid alumina is, beyond a doubt, reduced by carbon in electric furnaces, because the output of aluminium is greater than the number of ampères passing through the furnace could theoretically produce, and, also, because decomposition can be produced by a rapidly-alternating current, where electrolysis is out of question. The temperature in such furnaces is probably about 3,000°. Again, in a Pennsylvania iron blast furnace, in which the temperature is almost certainly not over 2,000°, as much as one per cent. of aluminium has been reduced into the iron. The liquid carbon in the iron in the crucible is here the reducing agent, reducing aluminium from a slag carrying as high as twenty-five per cent. of alumina.

It thus appears that both calculation and practice unite in showing that carbon begins to reduce alumina in the neighborhood of 2,000° C.

Hydrogen.—

$H^2 + O = 69{,}000$ calories (to liquid H^2O at 0°)

$= 58{,}100$ " (to vapor of water at 0°)

Specific heat of hydrogen $= 3{\cdot}3820 + 0{\cdot}0003t$ (*a*)

" " " oxygen $= 0{\cdot}2214 + 0{\cdot}00001875t$ (*b*)

" " " water vapor $= 0{\cdot}4208 + 0{\cdot}000182t$ (*c*)

$$H^2 + O \text{ (at } t°) = 58{,}100 + (2a + 16b - 18c)t$$
$$= 58{,}100 + 5{\cdot}9544t - {\cdot}001712t^2$$

We therefore have

$$Al^2 + O^3 = 387{,}200 + 192{\cdot}6t - 0{\cdot}1716t^2$$
$$3(H^2 + O) = 174{,}300 + 17{\cdot}863t - 0{\cdot}0051t^2$$

When these two expressions become equal to each other,

$$t = \overline{\underline{1770^\circ}}$$

This is just about the melting point of platinum, and may appear lower than can possibly be the fact; nevertheless, Mr. H. Warren, in England, has recently succeeded in reducing alumina to aluminium in a current of hydrogen gas, the alumina being inside a lime tube heated on the outside by the oxyhydrogen flame. It is hardly possible that the temperature inside the tube could have exceeded 2,000°; yet complete reduction to metallic globules was obtained.

This second confirmation of the calculations by experiment induces me to add, in conclusion, the following observations:

Acetylene gas, C^2H^2, has a negative heat of formation of 51,500 calories. It is, therefore, just by that much a more powerful reducing agent than C^2 and H^2 alone. The equation is:

$$Al^2O^3 + C^2H^2 = Al^2 + 2CO + H^2O$$

The thermal equations are:

$$\underline{Al^2 + O^3 = 387{,}200 + 196{\cdot}2t - 0{\cdot}1716t^2} \qquad (a)$$
$$2(C + O) = 55{,}570 + 5{\cdot}7648t - 0{\cdot}0005t^2 \qquad (b)$$
$$H^2 + O = 58{,}100 + 6{\cdot}7640t - 0{\cdot}0006t^2 \qquad (c)$$
$$C^2 - H^2 = 51{,}500 \qquad (d)$$

making $b + c + d = a$

$$t = \overline{\underline{1870^\circ}}$$

I am inclined to think that this highly endothermic compound would reduce alumina at an even lower temperature than this, because we have not only the benefit of its great heat of decomposition, but we also have, at the moment when it decomposes, the carbon and hydrogen atoms *in statu nascendi*, and we thus have all the advantages of a *nascent* reducing agent. I need not, to an audience of chem

ists, expatiate on the greater chemical activity of a nascent reducing agent.

The recent developments in the manufacture of calcium carbide and acetylene open up a possibility in the way of reducing alumina which may bear fruit. Allow me, at least, to claim for thermo-chemistry, rightly understood, that it is a most helpful guide to intelligent experiment.

LEHIGH UNIVERSITY, Bethlehem, Pa , February 19, 1895.

THE ACTION OF MAGNESIUM UPON THE VAPORS OF THE ALCOHOLS AND A NEW METHOD OF PREPARING ALLYLENE.*

BY EDWARD H. KEISER AND MARY B. BREED.

Under certain conditions magnesium is one of the most active elements. At high temperatures, as is well known, it has the power of reducing many of the most stable oxides, and in the absence of oxygen it can combine with nitrogen and form a nitride. That magnesium can also unite with carbon and form derivatives of the hydrocarbons will appear from the experiments described in this paper. An exhaustive study of the action of magnesium upon the oxides and hydroxides of the elements has been made by Winkler (*Ber. d. deutsch. Chem. Ges.* **23,** 120, 772, 2642), and Seubert and Schmidt (*Liebig's Annalen,* **267,** 218) have studied its effects upon the chlorides of the elements. So far as we know, no one has hitherto examined systematically the action of magnesium upon organic compounds containing oxygen. Preliminary experiments showed us that when magnesium is heated with organic oxygen compounds, such as alcohols, acids, ketones, etc., a reaction, accompanied by an incandescence of the metal, takes place at more or less elevated temperatures. Thus far we have studied in detail the

* Read at the stated meeting of the Chemical Section of the Franklin Institute, held December 18, 1894.

action of the metal upon several alcohols, and, as one of the results, have found a ready method of obtaining the unsaturated hydrocarbon, allylene, C_3H_4.

The experiments were conducted as follows: The magnesium, in the form of filings, was placed in a porcelain or iron boat, and heated in a combustion tube through which the vapor of the alcohol was passed. Before raising the temperature of the magnesium, the air in the apparatus was expelled by the alcohol vapor. At a low-red heat the magnesium begins to glow at one end of the boat, and usually, after a few moments, it becomes red hot throughout its entire mass. The boat and its contents are then allowed to cool down in the alcohol vapor. During the time that the magnesium is glowing, large volumes of gas are evolved from the tube. These gases were in each case collected in a gasometer, and subsequently analyzed.

The first alcohol examined was methyl alcohol. The magnesium, a at low-red heat, acts energetically upon it. After cooling, the residue in the boat has the appearance of a dark, black, coherent mass. When brought into water, this black residue slowly gives off a gas. If now a drop or two of a solution of ammonium chloride be added, a moderately rapid current of gas is given off. This gas has an odor like that of acetylene, but when it is conducted through an ammoniacal solution of cuprous chloride, the greenish-yellow precipitate of cuprous allylide is formed. In an ammoniacal solution of silver nitrate, a white crystalline precipitate of silver allylide is obtained. Both these precipitates, when they are filtered off, washed and dried, explode if they are heated up to about 150°. When treated with dilute nitric or hydrochloric acids, they dissolve with an evolution of allylene. The silver precipitate can be obtained in pure condition more readily than the copper compound. An analysis of the former gave the following result:

I. ·1292 grams gave ·1270 grams AgCl = 73·97 per cent. Ag.
Calculated for C_3H_3Ag, 73·45 " "

The gas which was given off during the time that the

magnesium in the porcelain boat was glowing in the methyl alcohol vapor, gave, on analysis, the following results:

CO_2	·8
CO	·6
CH_4	19·7
H	78·9
	100·0

The action of zinc dust upon the vapor of methyl alcohol has been examined by W. Jahn (*Monatshefte*, 1880, **1**, 378 and 675), who found that the chief products were hydrogen and carbon monoxide. As a by-product, a small quantity of marsh gas was obtained. It is evident, from the above analysis, that the action of the magnesium is essentially different, the carbon monoxide being practically absent in the products obtained when this metal acts upon the methyl alcohol. We have found that another metal, namely iron, decomposes the methyl alcohol vapor in the same way that zinc does. Thus, when the methyl alcohol vapor was passed through a tube containing iron, as, for example, a boat made of thin iron sheet, the alcohol was decomposed into carbon monoxide and hydrogen. An analysis of the gas thus obtained gave the following results:

CO_2	3·8
CO	26·8
CH_4	1·6
H	67·4
	99·6

In short, when methyl alcohol is passed over heated metals, such as iron or zinc, it is resolved into hydrogen and carbon monoxide; if it be passed over heated magnesium, the chief products are hydrogen and marsh gas.

The next alcohol examined was ethyl alcohol. The action in this case was similar to that described in the case of methyl alcohol. The residue remaining in the boat was treated with water and a few drops of ammonium chloride solution, and the gas that was given off was conducted through a series of bottles containing an ammoniacal solu-

tion of silver nitrate. The white crystalline precipitate, on analysis, gave the following percentage of silver:

I. ·1163 grams gave ·11365 grams $AgCl = 73·53$ per cent. Ag.
II. ·0979 " " ·09615 " " $= 73·89$ " "
Calculated for C_3H_3Ag, 73·45 " "

In this case also, allylene is given off when the magnesium residue is decomposed by water. The gases formed during the action have the following composition:

CO_2	0·0
CO	·4
C_2H_2	10·0
C_2H_4	4·0
CH_4	11·1
H	72·9
	98·4

The chief constituent again is hydrogen. Carbon monoxide is practically absent, as we should expect, knowing that this gas is reduced by magnesium. Acetylene and marsh gas are present in about equal quantities. Jahn found that zinc dust, at low temperatures, decomposes ethyl alcohol smoothly into ethylene and water, the latter being reduced to hydrogen by the zinc. At higher temperatures he obtained hydrogen, marsh gas and carbon monoxide, and a trace of acetylene. We have found that iron decomposes ethyl alcohol in very much the same way that zinc does at elevated temperatures. The gas obtained by passing ethyl alcohol over heated iron had the following composition:

	CO_2	·5
	CO	18·0
Unsaturated Hydrocarbons	$C_2H_2 + C_2H_4$	4·0
	CH_4	13·0
	H	63·8
		99·3

Propyl alcohol was examined in the same way. In this case the black magnesium residue is decomposed by water at the ordinary temperature, and the quantity of silver precipitate is very much greater than in the preceding cases. So readily is allylene obtained from propyl alcohol and magnesium by this method, that for the purpose of

preparing the gas for experiments on the lecture table it is much to be preferred to the ordinary method of decomposing propylene bromide with alcoholic potash. Analysis of the pure white silver allylide thrown down in the second wash-bottle from the generating flask gave, on analysis, 73·39 per cent. of silver.

·15605 grams gave ·1522 grams AgCl = 73·39 per cent. Ag.
Calculated for C_3H_3Ag = 73·45 " "

The precipitate in the first wash-bottle was not so pure; it evidently contained some silver acetylide. On analysis, ·20095 grams gave ·19985 grams AgCl, or 74·83 per cent. Silver acetylide contains a higher percentage, namely, 89·99 per cent. of silver.

An analysis of the gases formed when the magnesium acts upon propyl alcohol, showed that in general the action is similar to that which took place in the experiments with ethyl alcohol. The analysis gave these figures:

CO_2	0·0
CO	3·5
Unsaturated hydrocarbons	17·8
Saturated "	19 9
H	57·8
	99·0

The chief products of the decomposition of propyl alcohol, under the action of magnesium, are hydrogen and saturated and unsaturated hydrocarbons, the latter being present in nearly equal volumes. The same alcohol is decomposed by heated iron in a different way, the analysis of the gas having given the following values:

CO_2	·6
CO	16·4
Unsaturated hydrocarbons	16·7
Saturated "	23·6
Hydrogen	42·7
	100·0

With zinc dust, Jahn found that, at low temperatures, propylene and hydrogen are the chief products.

The other alcohols that have been examined are allyl, isobutyl and amyl alcohols. The first of these,

namely, allyl alcohol, is even better than normal propyl alcohol for the preparation of allylene. An abundant precipitate of silver allylide is obtained, and an analysis showed that it was free from silver acetylide.

I. ·17185 grams gave ·16735 grams AgCl = 73·27 per cent. Ag.
Calculated for C_3H_3 Ag = 73·45 " "

In this case the precipitate obtained in the first wash-bottle gave, on analysis, a result which showed that it contained no silver acetylide.

·16705 grams gave ·1620 grams AgCl = 72·97 per cent. Ag.
For C_3H_3 Ag = 73·45 " "

The ease with which, from a few cubic centimeters of propyl, or allyl, alcohols and a few grams of magnesium powder, an appreciable quantity of allylene silver can be obtained, makes this method of preparing allylene much more convenient than the one ordinarily used.

From isobutyl alcohol and magnesium, a residue was obtained, which, on treatment with water and ammonium chloride, gave a gas which, besides hydrogen, contained acetylene and allylene, as was shown by the percentage of silver in the silver precipitate.

·18335 grams gave ·18845 grams AgCl = 77·33 per cent. Ag.

From amyl alcohol the yield of silver precipitate was not very large, but here also the unsaturated hydrocarbon was allylene.

·08585 grams gave ·08365 AgCl = 73·31 per cent. Ag.

Other alcohols and organic compounds containing oxygen will be investigated in a similar way.

NOTES AND COMMENTS.*

ISOLATION OF HYDROGEN PEROXIDE.

Anhydrous hydrogen peroxide has at last been isolated by Dr. Wolffenstein in the laboratory of the Technischen Hochschule at Berlin, and the somewhat surprising fact demonstrated that this substance, which has hitherto been regarded as possessing but little stability, is capable of actual distillation with scarcely any loss under reduced pressure.

* From the Secretary's monthly reports.

In attempting to concentrate solutions of hydrogen peroxide in vacuo by the method of Talbot and Moody, and also in the open air upon the water bath, a solution as strong as sixty-six per cent. H_2O_2 was obtained, but with a loss of over seventy per cent. of the original amount of peroxide employed. Moreover, it was found that when the common commercial three per cent. solution is concentrated, the percentage of H_2O_2 may be brought up to forty-five without the loss of any considerable quantity of the peroxide by volatilization, but that as the concentration continues to rise above this limit the volatilization of the peroxide increases at a very rapid rate; for the great loss was proved to be due not to decomposition, but to actual vaporization of the substance. Evidently hydrogen peroxide is remarkably stable at the temperature of a water bath. An attempt was therefore made to actually distill it under reduced pressure. A quantity of commercial peroxide which had been further concentrated until it contained about fifty per cent. H_2O_2 was first purified from all traces of suspended impurities, and at the same time still further concentrated by extraction with ether. After evaporation of the ether the solution was found to contain seventy-three per cent. H_2O_2.

This solution was then submitted to distillation at the temperature of the water bath and under the reduced pressure of sixty-eight millimetres of mercury. The distillate was received in two fractions, boiling at 71°–81° and 81°–85° respectively. The first fraction contained forty-four per cent. H_2O_2, while the latter was found to contain no less than 90·5 per cent. Upon again fractionally distilling the latter product, a large proportion distilled at 84°–85°, and this fraction proved to be practically pure H_2O_2, containing over ninety-nine per cent. of the peroxide. The liquid thus isolated is a colorless syrup which exhibits but little inclination to wet the surface of the containing vessel. When exposed to the air it evaporates. It produces a prickly sensation when placed upon the skin, and causes the appearance of white spots, which take several hours to disappear again. As regards the much-discussed and disputed question of the reaction of hydrogen peroxide toward litmus, Dr. Wolffenstein finds that even when the pure liquid is made strongly alkaline with soda and again distilled, the distillate exhibits strong acid characters, so that the acid nature of hydrogen peroxide must be regarded as fully established. It is finally shown that the use of ether in assisting the concentration is by no means essential. Ordinary commercial three per cent. peroxide can be immediately subjected to fractional distillation under reduced pressure, and a fraction eventually isolated, consisting of the pure substance boiling at 84°–85° under a pressure of sixty-eight millimetres.—London *Nature*.

PROGRESS OF IRRIGATION.

The *Scientific American* gives the following interesting summary of the progress which is being made in the work of reclaiming, for the purposes of agriculture, the vast tracts of arid land in the far West:

The irrigated and irrigable lands of the western part of the United States are mainly included between the one-hundreth meridian and the Pacific Ocean, and comprise, according to official surveys, about 610,000,000 acres.

Within this great extent of country are nearly all possible combinations of soil and climate. In a general way, however, four great classes may be distinguished. These are desert, pasture, fire-wood and timber lands. Of these, the desert land is practically valueless, the pasture land is too arid to support vegetation and may be used only as a pasturage, and only the latter two divisions are more or less fertile. The irrigated sections are included in the desert and pasture lands. At present some 3,631,381 acres (or less than six-tenths of one per cent. of the entire region) have been provided with an artificial water supply sufficient to raise crops.

The proportion of this desert or pasture land which may, in the future, be brought under irrigation depends, of course, upon the thoroughness and ingenuity with which the water supply is utilized, but it is probable that it will be under three per cent. of the entire area. Statistics show, however, that irrigation is a profitable measure and cannot be neglected. The average cost of water for irrigation throughout this section is at the rate of $8.15 per acre. Applying these figures to the total acreage the total first cost of irrigating the lands last year was about $30,000,000, and the total value of the water right was $94,412,000, the increase of valuing being $64,800,000, or 218·84 per cent. of the investment. The estimated first cost of the irrigated lands from which crops have been obtained was $77,500,000 in 1889, and their present value, including the improvements, is $296,850,000, showing an increased value of $219,360,000, or 283·08 per cent. of the investment in the land. The average value of the crop raised was $14.89 per acre, or a total of $53,057,000. This, it must be considered, exhibits merely the cost and value of irrigation in the arid regions. The value of the unutilized water supply can scarcely be estimated.

During the past four years the Federal Government has done much to further the work of irrigation by establishing an irrigation survey and by appointing State engineers in California, Colorado and Wyoming, whose duties are practically confined to irrigation.

At present the irrigation of this region is carried on by what is called gravity irrigation.

The different systems adopted by modern engineers may be classified as perennial, periodical and storage work, by irrigation from artesian wells and from sub-surface sources. The perennial irrigation includes the supply of water from canals which receive their supply from streams which give a constant supply of water throughout the entire year.

Periodical irrigation includes the canals which have a supply only at certain seasons of the year. A more common plan, however, is the storage system. The dams for this system are generally constructed on intermittent streams for the purposing of receiving and preserving their flood waters.

The irrigation from artesian wells is practiced wholly by means of canals, which convey the water to the land directly from the wells. And the irrigation from ground-water sources is performed by tunnels under the beds of streams, which tap some water-bearing stratum, or by cuts in sloping ground, by wells to collect the ground-water and by similar contrivances.

The work of irrigation calls for much skill and scientific knowledge.

Climate, geology and topography must all be considered in the work. It is to be hoped that the skilled engineers now at work on the subject will provide an economical and efficient system for the future.

AS TO THE SIN OF PLAGIARISM: SOME REFLECTIONS, IRONICAL AND OTHERWISE.

There are occasions when the display of virtuous indignation is proper, even highly praiseworthy, and the writer can sympathize with the sentiment which induced the Western Foundrymen's Association, at one of its recent monthly meetings, to expurgate its records by withdrawing therefrom a paper which had manifestly been copied, without credit to the author, from a published book.

The history of the event to which the above remarks apply is given in sufficient detail for the present purpose, in the following extract from the proceedings of the meeting of that Association, which appeared in *The Iron Age* of February 28, 1895, viz.:

PLAGIARISM OF SISSON'S "A B C OF IRON."

The Investigating Committee, appointed by the Chair, returned and presented the following report:

"Your committee respectfully report that they have compared the paper presented by Chas. Johnson with Sisson's "A B C of Iron," and find that it is almost entirely copied from that book. We therefore recommend that the following resolution be adopted, and that the Secretary be authorized to carry out its instructions:

"*Resolved*, It having been found that the paper by Charles Johnson, read at the last meeting of this Association, should not have been presented as an original paper, the Secretary is instructed to withdraw it from the records of the Association, together with all resolutions relative thereto."

The report of the committee was adopted and ordered spread upon the records.

The reading of this somewhat severe public rebuke aroused the curiosity of the writer to examine the book with the alphabetical title; for, as imitation is said to be the sincerest form of flattery, it was reasonable to believe that what was worth the trouble—not to mention the risk—of stealing, must have some merit or value.

Here is what the examination disclosed:

Sisson's book is an octavo of ninety-nine pages, of which about fifty pages are actually credited, either by honest quotation marks or by presenting the names of authors (though in *very* subordinate type), to their legitimate sources.

With the possible exception of a chapter of three pages on "How to Reduce Cost of Mixture," concerning which Mr. Sisson is entitled to the benefit of the doubt, the remainder of the book is simply a piece of patchwork made by a bungling amateur, with the aid of scissors and paste-pot and conjunctions.

The source of much of Sisson's uncredited material is made sufficiently clear by the method of the deadly parallel column employed in the following exposition:

"PIG IRON,

"Including the Relation Between its Physical Properties and its Chemical Constituents.

"By Alex. E. Outerbridge, Jr.,

"*Journal of the Franklin Institute, March, 1888.*

"Manufacturers are beginning to realize that pig iron is not a simple substance, but is, in reality, an alloy, composed of a number of dissimilar elements; that its physical characteristics, such as strength, elasticity, etc., depend upon the percentages of these constituents, and that pure iron, like pure gold, is always the same thing physically and chemically, no matter from what source it may be obtained.

"We believe that the time is coming when pig iron will be sold on its chemical analysis, instead of on the crude methods of grading at present in vogue, and further, that, as the naturalist can accurately tell the genus of an animal from an examination of a single bone, so the analyst will tell the physical qualities of a mass of iron from an analysis of its component parts.

"The element which exerts the most vital influence upon the character of pig iron, is carbon.

"Carbon exists in pig iron in two distinct forms, and upon the relative proportion of each depends, in great measure, the character of the metal.

"Silicon stands next in importance to carbon, in respect to its effect upon the character of the metal. It exerts a controlling influence upon the chilling properties of the iron, since its tendency is to prevent the chemical combination of the carbon and iron. * * * The notion has long prevailed (like many other fallacies born of ignorance) that silicon produces 'blow-holes,' or unsound castings, but such is not the case.

"Phosphorus, as an element in pig iron, tends to render the molten metal very limpid, so that it will take an extremely fine and sharp casting from the most delicate patterns.

"THE A B C OF IRON.

"By Chas. W. Sisson.

"*Louisville, Ky., 1893.*

"Manufacturers now realize that pig iron is not a simple substance, but is, in reality, an alloy, composed (sic) of a number of elements very dissimilar; that its physical characteristics, strength, elasticity, etc., depend upon the percentages of these elements (third line of Introductory, *et seq*). * * * Pure iron, like pure gold, is always the same thing physically and chemically, no matter from what source it comes (p. 44). * * *

"We feel that the time is not far distant when all iron must be sold on basis of analysis (p. 45). * * *

"There is no reason why a chemist should not tell the physical qualities of pig iron from an analysis as easily and accurately as the naturalist can tell the genus of an animal from an examination of a single bone (p. 44).

"Carbon exerts the most vital influence on pig iron of all the elements (p. 21).

"It (carbon) exists in pig iron in two distinct forms, the combined and graphitic, and upon the relative proportion of each, in a great measure, depends the character of the metal (p. 21).

"Next to carbon, silicon is the commonest and most abundant constituent of cast iron. * * * The effect of silicon is to change the combined carbon into graphitic carbon. * * * It increases the fusibility and fluidity of iron, lessens the formation of blow-holes, and reduces shrinkage (p. 25).

"Its tendency (phosphorus) is to render the metal very limpid, so that it will take an extremely fine and sharp casting from the most delicate patterns.

"The famous Berlin castings of reproductions in iron of ancient armor, and other ornamental objects, are obtained by using iron rich in phosphorus, but it possesses the disadvantage of rendering the metal brittle and unfit for many practical uses. * * * The percentage of phosphorus in pig iron may vary from a trace to one and one-half per cent.

"Sulphur is, without doubt, the most deleterious substance found in pig iron. The other elements all produce effects which may be beneficial for certain purposes, but sulphur is an enemy greatly to be dreaded, since it has a strong affinity for iron, combining with it at a low temperature. * * *

"The presence of sulphur in pig iron is due mainly to bad fuel.

"The chemistry of iron, in its connection with the manufacture of Bessemer steel, has, from the necessities of the case, been carried to a fine degree of perfection, but it is a matter of surprise that so little is known practically in the foundry and workshops in regard to the cause of these wide variations, which are a frequent source of difficulty in manipulation of the metal, and loss of time, money and labor.

"The subject is, however, beginning to attract a share of the scientific attention which has been bestowed upon the chemistry of steel, and upon which the success of that industry so largely depends.

"NOTES ON THE BLAST FURNACE.

"BY JOHN HARTMAN.

"*Journal of the Franklin Institute*, *August*, *1892*.

"STANDARD NO. 1. PIG IRON.

"*Gray*.—A large, dark, open-grain iron, softest of all the numbers, and used exclusively in the foundry. Tensile strength, low. Elastic limit, low. Fracture, rough. Turns soft and tough.

"NO. 2. PIG IRON.

"*Gray*.—A mixed large and small dark grain, harder than No. 1 iron.

"The famous Berlin castings of reproductions in iron of ancient armor, and other ornamental objects, are obtained by using iron rich in phosphorus, but it possesses the disadvantage of rendering the metal brittle and unfit for many practical uses (p. 29). * * * The percentage of phosphorus in pig iron varies from a trace to one and one-half per cent. (p. 30).

"Sulphur is, without doubt, the most deleterious substance found in pig iron. The other elements all produce effects which may be beneficial for certain purposes, but sulphur is the enemy dreaded by all, on account of its affinity for iron combining with it at a low temperature (p. 34).

"The presence of sulphur in pig iron is due mainly to its absorption from the fuel (p. 34).

"The success of the steel industry is largely due to the scientific attention bestowed upon the chemistry of steel, and its manufacture has been carried to a fine degree of perfection. There is no reason why iron should not reach the same perfection and be sold by analysis, as steel is (p. 45).

"THE A B C OF IRON.

"BY CHAS. W. SISSON.

"*Louisville, Ky.*, *1893*.

"*No. 1 Foundry* is the darkest of the numbers as well as the softest, as it contains the most graphitic carbon, and is used exclusively in the foundry. In appearance the fracture is dark in color, rough, open grain; tensile strength and elastic limit, low; turns soft and tough (p. 37).

"*No. 2 Foundry* is more generally used with foundry than any other

and used exclusively in the foundry. Tensile strength and elastic limit higher than No. 1. Fracture, less rough than No. 1. Turns harder, less tough and more brittle than No. 1.	grade. The grain is not so open and large as No. 1 Foundry, but the iron is harder and stronger, although less tough and more brittle (p. 37).
"No. 3. Pig Iron. " *Gray.*—Small, gray, close grain, harder than No. 2 iron, used either in the rolling mill or foundry. Tensile strength and elastic limit higher than No. 2. Turns harder, less tough and more brittle than No. 2. * * * Graphitic carbon lower, and combined carbon higher than No. 2. * * * The strength for tension culminates in No. 3 pig iron.	"*No. 3 Foundry* is used for both mill and foundry purposes. It is much stronger than Nos. 1 and 2, the grain being closer and more compact. It turns hard, is less tough and more brittle than No. 2. The strength for tension seems to reach its limit in this grade. * * * The percentages of graphitic carbon and silicon are smaller and contained carbon larger than in No. 2" (p. 38).
"No. 4. Pig Iron. " *Mottled.* — White background, dotted closely with small black spots of graphitic carbon, little or no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit lower than No. 3. Turns with difficulty, less tough and more brittle than No. 3 * * * Graphitic carbon lower and combined carbon higher than No. 3.	"*Mottled.*— * * * Mottled iron is used exclusively for puddling purposes. Turns with great difficulty, less tough and more brittle Gray Forge. Graphitic carbon and silicon lower than in Gray Forge and combined carbon higher" (p. 38).
"No. 5. Pig Iron. " *White.*—Smooth, white fracture, no grain, used exclusively in the rolling mill. Tensile strength and elastic limit much lower than No. 4. Too hard to turn and more brittle than No. 4. * * * The patches are small and closer, but no grain. No graphitic carbon, all combined carbon."	"*White.* — * * * It has a smooth, white fracture, no grain, and is used exclusively in a (sic) rolling mill; tensile strength and elastic limit very low; too hard to turn or drill, as the carbon in this grade is about all in the combined state" (p. 39).

Other "adaptations," familiar though elusive, crop out elsewhere in this interesting production of Mr. Sisson. But enough has been shown in the comparative exhibit to make it clear, that however proper and even praiseworthy may have been the virtuous indignation of the foundrymen over the unhandsome behavior of Mr. Johnson, the emptying of the vials of their wrath on his devoted head for the crime of re-cribbing from Sisson, was not only too severe upon the unlucky subject of their displeasure, but under the circumstances, was an act which, without violating the proprieties, might even be called ridiculous.

Mr. Sisson's method of "adapting" other men's work is simplicity itself, and consists merely in judiciously sprinkling, throughout his book, portions of sentences which were continuous in the original. He leaves himself a loop-hole for escape from the charge of moral delinquency, in the event of detection, by the comprehensive statement in his introduction, that "except

where extended quotations are given no mention is made of the authority, for the reason that it often became necessary to change the language to have it simple and readily understood." (Here's richness, as Mr. Squeers would say).

It is evident that there is nothing mean about Mr. Sisson. He not only appropriates the work of others without credit, but is generous enough also to assume to improve upon it.

As an example of such improvement take the following: In speaking of silicon in his lecture, Mr. Outerbridge had said: "Its tendency is to produce an exceedingly fluid iron, retaining its heat for a long time, owing, I believe, to a fact not generally known, that the specific heat of iron rich in silicon is much higher than that of a similar grade of iron containing but little of that element." It would seem that there was too much "high science" in this for Mr. S. He accepted the "fluidity," but evidently thought the "specific heat" part of the statement needed simplification, and hit upon "fusibility" as a synonym. Accordingly, the sentence is made to read: "It increases the fusibility and fluidity of iron."

Again, Mr. Outerbridge had found as the result of some hundreds of experiments that the addition of a small quantity of ferro-manganese (one pound in 600 pounds of iron), increased *strength* forty per cent. and decreased chill. Mr. S. says (p. 32): "An increase of one per cent. manganese has increased the *hardness* forty per cent.;" and in the next sentence adds: "Mr. Keep's tests show that manganese does not increase chill."

As increased chill and increased hardness go together, irrespective of manganese, this wild shot at "simplifying" what he did not understand, if not quite a bull's-eye, is just near enough to be a "bull;" and, with other attempts of the author at simplification—not to speak of his frequent efforts to improve the accepted spelling of English—may stand as a conspicuous illustration of the fact that "a little knowledge is a dangerous thing."

W.

TESTS OF NON-CONDUCTING PIPE COVERINGS.

A series of tests have been made at the St. Louis Water Works by John A. Laird, to select the most suitable covering for pipes, boiler shells, etc., in the new pumping station at the Chain of Rocks. The report appears in the "Proceedings" of the Association of Engineering Societies. There were purchased asbestos sponge moulded sectional covering, asbestos fire-felt sectional covering and magnesia sectional covering, all for one-inch pipe. Also, asbestos sponge cement felting, asbestos cement felting, plastic magnesia and fossil meal. Tests were also made on plaster of Paris and sawdust, moulded into covering for one-inch pipe.

The different coverings were subjected to chemical examination by Mr. Wixford, chemist of the water works, with the following approximate results:

Asbestos Sponge (Moulded).

Plaster of Paris	95·8
Fibrous asbestos	4·2

Asbestos Fire Felt.

Asbestos	82·
Carbonaceous matter not determined	18·

Magnesia (Sectional).

Magnesia	92·2
Fibrous asbestos	7·8

Magnesia (Plastic).

Magnesium carbonate	93·
Fibrous asbestos	7·

Asbestos Cement Felting.

(Probably) powdered limestone	64·5
Plaster of Paris	3·5
Asbestos	32·

Asbestos Sponge Cement Felting.

(Probably) powdered limestone	59·
Plaster of Paris	10·
Asbestos	31·

Fossil Meal.

Insoluble silicate	80·
Carbonaceous matter, hair, paper, sawdust, etc.	12·
Soluble mineral matter	8·

On all condensation tests the gauge pressure was held at twenty-five pounds. The water was drawn off every fifteen minutes and was measured in cubic centimeters. Each test was continued for four hours. The mean results are tabulated below.

Condensation Tests.

Name of Covering.	*C.c. Condensed Per Hour.*
Magnesia (plastic)	334·
Magnesia (sectional)	335·3
Asbestos fire-felt	367·5
Asbestos sponge (moulded)	371·3
Fossil meal	376·2
Plaster of Paris and sawdust	438·
Asbestos fire-felt cement	563·7
Asbestos sponge cement	604·
Bare pipe	1085·

On the question of durability, Mr Laird states that the magnesia sectional covering which has been on pipe at Bissell's Point for four years shows no signs of deterioration; also that the asbestos sponge moulded covering which has been on pipes at Harlem Creek for less than two years is becoming soft, and the plaster of paris seems to be reduced back to the original powder, with nothing but the fibrous asbestos to hold it together. Another question is that of steam pressure. The experiments were made at the High Service Station, No. 2, and it was found convenient to have all tests made at twenty-five pounds gauge pressure. As the working pressure at Chain of Rocks will be at least 125 pounds, the relative efficiency of insulation will be slightly changed, but, in Mr. Laird's opinion, not enough to change the conclusions here arrived at.—*Iron Age.*

BOOK NOTICES.

A Laboratory Manual of Physics and Applied Electricity.—Arranged and edited by Edward L. Nichols, Professor of Physics in Cornell University. In two volumes. Vol. 1, Junior Course in General Physics. By Ernest Merritt and Fredk. J. Rogers. New York and London: Macmillan & Co. 1894.

One of the best evidences of the remarkable changes in the methods of instruction in modern schools of engineering in the United States is afforded by the text-book now under consideration. The plan of the work assumes that the student has access to physical apparatus and that he shall be required to conduct, under his own supervision, the experimental work of testing and verifying the principles of the sciences on which his intended professional work is based. Nothing more unlike the methods of twenty years ago in our best schools could be imagined.

The present volume has been edited by Professor Nichols, with the aid of his assistant instructors, to supply the needs of the student in the physical praktikum, which the existing manuals on physics are found to meet only in an inadequate manner. The method pursued is to follow the statement of a proposition by an experimental demonstration bearing directly upon it, and to verify each step as the student goes along. A text-book for more advanced students, arranged on the same general lines, is presently to follow. W.

The Steam Engine and Other Heat Engines.—By J. A. Ewing, M.A , B.Sc., F.R.S., M. Inst., C.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. University Press: Macmillan & Co. $3.75.

This work, by an author of acknowledged reputation, not only in his own line—that of mechanics—but also in the allied subject of electricity, naturally excites anticipations of a favorable character. Study of its pages proves no disappointment. The book is, in some respects, quite different from any other text-book on the subject, and is written in the clear and masterly style always characteristic of Professor Ewing's work, and happily different from the confused and complicated verbiage of the majority of English technical writers.

The work is, as a whole, based on the article on "Steam Engine," written by Professor Ewing for the Encyclopædia Brittanica, but is much more complete than that article, and systematized, and in its present form is offered so as to be more useful for reference.

The aim of the author has been to collate and make evident the relation of steam-engine theory and practice. Starting out with a chapter on the early history of steam and heat engines, and tracing its gradual evolution, there follow a number of chapters devoted to the dynamic theory of steam and the application of this theory in practice. The use of diagrams is quite extensive, in particular that of the Entropy temperature diagram, as a means of exhibiting thermodynamic actions; then follows a study of the actual behavior of steam

in the cylinder, and a treatment of the subject of compound expansion. The well-known work of Dr. Emery is mentioned and quoted. The subject of valve gears and the theory of governing also receives considerable attention.

The discussion of what constitutes the best type of steam engines in different conditions, as evidenced by present-day practice, is rather slurred over, but few forms receiving any attention. In a practical work, while deprecating the tendency to profuse description too frequently indulged in by many writers, it would, nevertheless, seem as if some space, devoted to a detailed discussion of a number of characteristic types of engines, would have been valuable. Thus, for example, a consideration of the relative merits of high- and low-speed engines; the pros and cons regarding various types of compound engines; the practical advantages gained by working with high steam pressures, etc., are matters concerning which the average engineer requires fuller exposition.

The steam turbine has but a few pages given it, although many readers would have welcomed full information from so authoritative a writer, there being no question but that this form of motor is one of those things which, logically, should develop into a prime mover of considerable practical value.

The closing chapter is on air, gas and oil engines. Upon this subject, also, greater completeness would have been desirable. Engines of this type are proving themselves of rapidly increasing value, in view of the downward tendency in the price of gas and the large development of natural gas supplies. The literature of the subject, as is well known, is exceedingly incomplete and old-fashioned.

On the whole, the book is a valuable one and offers much that is suggestive, while the exposition, as previously mentioned, is clear and to the point.

E. G. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 20, 1895*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1895.

Mr. H. R. HEYL, Vice-President, in the chair.

Present, 172 members and thirty-two visitors.

Additions to membership since last report, nine.

The Secretary read letters from Messrs. H. R. Heyl and Chas. A. Hexamer, accepting election, respectively, to the office of Vice-President, and to membership in the Committee on Science and the Arts. Also, a communication from the Wyoming Historical and Geological Society of Wilkes-Barre, Pa., announcing the death of Mr. Sheldon Reynolds, the late president of the society and life member of the Franklin Institute. It was ordered that due notice of the fact be entered upon the minutes of the meeting.

The Secretary announced that, in accordance with the action taken at the

stated meeting, held February 20, 1895, the President had appointed a special committee, of which Mr. William Sellers was named as chairman, to consider the expediency of co-operating with the *Verein Deutscher Ingenieure* in an international movement for the unification of screw-thread standards. A communication was read from the chairman making a report of progress.

Mr. Lawrence T. Paul was elected to fill the vacancy in the Board of Managers, caused by the election of Mr. Heyl to the office of Vice-President.

The paper of the evening was entitled "The Carbides and Acetylene Commercially Considered," by Mr. Thos. L. Willson and Dr. J. J. Suckert, of New York.

The paper gave an exhaustive historical account of the subject, leading up to the interesting discovery, by Mr. Willson, of a practical method of producing, on the commercial scale, in the electric furnace, the metallic carbides, and especially calcium carbide; the production therefrom of acetylene, by bringing the carbide in contact with water; and the industrial bearings of the several inventions embraced in Mr. Willson's work, principally in connection with questions of the cheap production of acetylene for illuminating purposes.

The paper was profusely and brilliantly illustrated by experiments, showing the generation of the gas by the decomposition of water, the solidification of acetylene with the cold produced by the vaporization of the liquefied gas, and the illuminating value of acetylene. Acetylene forms a snow-white solid, showing by the thermometer a temperature of — 118° F. Mercury surrounded by the solid substance was readily frozen. The brilliant whiteness of the acetylene flame burning from a series of one-foot Bray tips was capitally shown by comparison with the ordinary coal gas flame, and incandescent and arc electric lights, simultaneously in operation. The shadow of a common gas flame from a six-foot burner was distinctly shown projected on a white screen with the aid of one of the small acetylene jets above referred to.

The historical portion of the paper was further illustrated by the exhibition of a complete suite of specimens of various metallic carbides and related electric-furnace products, and of interesting derivatives, such as benzol, styrol, nitro-benzol, naphthalene, etc.

The paper evoked an extended discussion, and will appear in due course in the *Journal*.

At the close of the discussion, Mr. A. E. Outerbridge, Jr., moved a vote of thanks to the authors for their extremely interesting and valuable communication. The motion was numerously seconded and was adopted amid pronounced applause.

The Chairman, in a few appropriate remarks, expressed to Messrs. Willson and Suckert the appreciation and thanks of the Institute for their admirable presentation of the subject, and the meeting adjourned.

WM. H. WAHL, *Secretary*.

ERRATUM: Art. Outerbridge; March *Journal*, p. 226, line 8 from top; for IX *read* I. x.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIX. MAY, 1895. NO. 5

[*Proceedings of the Institute, Stated Meeting held Wednesday, March 20, 1895.*]

JOS. M. WILSON, President, in the chair.

Paper of the Evening:

THE CARBIDES AND ACETYLENE COMMERCIALLY CONSIDERED.

BY T. L. WILLSON AND J. J. SUCKERT, PH.D.

DR. SUCKERT:—MEMBERS OF THE FRANKLIN INSTITUTE, LADIES AND GENTLEMEN:

Before entering upon the subject matter of this paper, namely, the commercial consideration of the carbides and acetylene, we believe that a brief history of these compounds, their methods of formation and their chemical and physical properties, will be of interest to you. That carbon will combine directly with various metals under the influence of heat, has long been known to chemists, but these compounds, generally known as "carbides," have been but

imperfectly studied, and, with the exception, perhaps, of the carbides of iron, are hardly known.

The only group of carbides which interests us this evening is that of the carbides of the alkali and alkaline-earth metals, such as the potassium, sodium, barium, strontium and calcium carbides; for the reason that these are the only carbides which, when brought into contact with water, will decompose it, forming generally the hydrated oxide of the metal and acetylene gas. Of these latter carbides, the combination of calcium with carbon has the greatest commercial possibilities on account of the low first cost of the raw materials which enter into this combination, namely, lime and coal, the abundant deposits of same in all quarters of the globe, and the commercial value represented by the by-product, hydrate of lime, which is obtained in large quantities by the decomposition of the calcium carbide with water.

The history of the discovery and methods of production of this group of carbides may briefly be stated, as follows:

The first authentic reference to this subject was the discovery, by Sir Humphrey Davy, that carbon and potassium, when heated to a temperature sufficiently high to vaporize the potassium, formed a compound which, after cooling, would effervesce with water.

Berzelius, in 1836, determined that the black substance formed in small quantities as a by-product in producing potassium from potassic carbonate and carbon, was carbide of potassium.

Woehler, in 1862, prepared calcium carbide by fusing an alloy of zinc and calcium with carbon, and ascertained that it decomposed by contact with water forming calcic hydrate and acetylene.

Berthelot, in 1866, described sodium carbide or acetylene sodium. He produced it by the following method: Metallic sodium, when slightly heated in acetylene gas, puffs up and absorbs acetylene with the formation of the compound C_2HNa. At a dull red heat sodium destroys acetylene, forming a black carbonaceous mass, C_2Na_2. The reaction is expressed by the following formula: ($C_2H_2 + Na_2 =$

$C_2Na_2 + H_2$). This compound, C_2Na_2, in contact with water, regenerates acetylene.

From 1866 until 1888, a period of twenty-two years, nothing further has been recorded of scientific work done in this direction; as a matter of fact, the compounds so produced were not only very impure, but their cost of production also was so great as to render their commercial use prohibitory; they were considered as curiosities and looked upon by scientists as such. In 1888, Mr. T. L. Willson began a series of experiments relating especially to the reduction of refractory metallic oxides by carbon, in an electrical furnace. By this method the reductions were to be accomplished by the heat effect of the current alone, and not by electrolytic action.

The results of these experiments, which were numerous, and which extended over a period of years, developed some very interesting data as to the action of intense heat on refractory bodies generally, and especially as to the formation of carbides in large quantities. Mr. Willson found that lime, baryta, strontia and even alumina, when subjected to the intense heat of his electric furnace, were liquefied and formed a molten mass, which could be brought to ebullition. An addition of carbon thereto caused a decomposition of the oxide, carbon monoxide being formed, while the fused metal united instantly with the excess of carbon, previously introduced, to form a carbide. Further experiments developed the fact that when a mixture of powdered lime and coke dust was introduced into the furnace, the mixture would melt down to a thick syrupy mass of practically pure carbide of calcium, and that this, when removed from the furnace and brought in contact with water, evolved acetylene gas in large quantities. The carbides of barium, strontium and aluminum also were prepared in the same manner, and the specimens now before you are the results of these earlier experiments.

We will now introduce a small quantity of each of these carbides into different vessels containing water at ordinary temperature. The carbides of barium, strontium and calcium decompose water readily, forming the respective

hydrates of their metallic oxides and acetylene gas, which we now ignite as it is being evolved in each vessel; the resulting gas, as you observe, burns with a luminous sooty flame (see *Fig. 1*). As the carbide of aluminum does not react with water at ordinary temperatures, no gas is evolved from the fourth vessel.

This substantially completes the history of the alkali and alkaline-earth metal carbides up to the date of Mr. Willson's discovery.

The physical and chemical properties of pure calcium carbide, as first prepared in the Willson furnace, and which we now hand you for inspection, is a dark-brown, dense substance, having a crystalline metallic fracture of blue or brown appearance, and a specific gravity of 2·262; it evolves a peculiar odor when exposed to the atmosphere, due to the action of atmospheric moisture. In a dry atmosphere it is odorless. When exposed to the air in lumps, it becomes coated with a layer of hydrate of lime, which, to a great extent, protects the rest of the substance from further deterioration by atmospheric moisture. It is not inflammable, and can be exposed to the temperature of the ordinary blast furnace without melting. When exposed to the flame of a Bunsen blast-lamp it can be heated to a white heat, the exterior only being converted into lime. When brought into contact with water, or its vapor, at ordinary temperatures, it is rapidly decomposed, one pound generating, when pure, 5·892 cubic feet of acetylene gas at a temperature of 64° F. It also decomposes with snow at a temperature of — 24° F. It is not acted upon by the vapor of water at high temperatures. It abstracts moisture readily from alcohol, also from liquefied ammonia gas, rendering the latter anhydrous. If small pieces are treated with common sulphuric acid, a violent reaction ensues. Acetylene is generated with considerable increase in temperature. If, however, large pieces are plunged into common sulphuric acid, the reaction is feeble.

An exhaustive series of experiments, made by Dr. H. Schweitzer, of New York, have shown that when treated at a red heat with dry muriatic acid gas, the carbide is decomposed with the formation of free carbon and small quanti-

ties of a yellow substance easily soluble in ether. When treated with steam at different temperatures, (up to 428° F.), and different pressures (up to 35 atm.), the material was decomposed with the formation of but small quantities of the same yellow substance, and not in sufficient quantity for further examination.

Benzol, nitro-benzol, phenol, aniline, toluidine, and other organic compounds, gave no reaction when treated with carbide of calcium alone, and in the presence of water, at varying pressures and temperatures. It would appear from the foregoing to be a very inert body in its action on other compounds, and in view of this fact, the ease with which it decomposes water at ordinary temperatures is remarkable.

When treated with water in a closed vessel properly cooled, acetylene gas continues to be evolved from the material at pressures exceeding 75 atm. Calcium carbide has the chemical formula CaC_2, and contains in 100 parts 62·5 parts of calcium and 37·5 parts of carbon.

The gaseous product of the decomposition of the alkali and alkaline earth metal carbides with water, namely, acetylene, is an unsaturated hydrocarbon of the series $CnH2n—2$, having the chemical formula C_2H_2, and containing, therefore, in 100 parts, 92·3 parts of carbon and 7·7 parts of hydrogen.

It was first recognized, and its chemical constitution determined, by Berthelot, in 1849. It has heretofore been formed in small quantities by passing ethylene, or the vapors of alcohol, wood alcohol, ether, and other organic compounds, through a red-hot tube. It is present in coal gas to the extent of 0·06 per cent., and water gas contains almost 1·0 per cent. It has also been formed by passing hydrogen gas between carbon points brought to incandescence by the electric current, which is the first recorded synthesis of an organic compound directly from its elements. It can also be produced by the incomplete combustion of the vapors of ether, amylene, etc.; or of illuminating gas, in the interior of a Bunsen burner; by passing the vapor of chloroform over red-hot copper; or from chloroform and potassium

amalgam; or from chloroform and sodium; or by the electrolysis of fumaric and malic acids; by passing the vapor of ethylene chloride over red-hot soda lime; and finally, by allowing ethylene bromide to drop in a boiling concentrated solution of alcoholic potash, passing the impure acetylene into an ammoniacal cuprous chloride solution, washing the red precipitate with water, and, whilst still moist, boiling it with concentrated hydrochloric acid.

Acetylene is a colorless gas, having a penetrating pungent odor somewhat resembling garlic, which is of great importance in its application to household illumination, as it renders the slightest escape of gas in a room easily detectable. It has a specific gravity of 0·91, and burns with a luminous sooty flame. It is soluble in water in about the same proportions as carbon dioxide, that is, at 64° F. water will absorb its own volume of the gas. Absolute alcohol and glacial acetic acid dissolve about six times their volume. It is practically insoluble in saturated brine, 100 volumes absorbing but five volumes of the gas, whereas paraffine will absorb two and one-half times its volume. By heating acetylene to the softening point of glass, benzol (C_6H_6), styrolene (C_8H_8), naphthalene ($C_{10}H_8$), anthracene ($C_{14}H_{10}$), and reten ($C_{18}H_{18}$), are formed.

With an alkaline solution of permanganate of potash, acetylene is oxidized to oxalic acid, and with a dilute solution of chromic acid to acetic acid. By treating acetylene-copper with zinc and ammonia, ethylene is formed, and a mixture of acetylene and hydrogen, brought in contact with platinum black, forms ethane. By the electric spark, acetylene is resolved into carbon and hydrogen, at the same time a fluid and a solid poly-acetylene are formed; the latter resembles horn, and is insoluble in the ordinary solvents. A mixture of nitrogen and acetylene is converted by the induction spark into hydrocyanic acid.

It may be heated to a temperature of 370° F., and under a pressure of 43 atmospheres, without decomposition.

The gas can readily be condensed to a liquid, as is evidenced by the following table, the pressures being considerably less than those required for carbon dioxide.

Acetylene.		Carbon Dioxide.	
Fahr.	*Atmospheres.*	*Fahr.*	*Atmospheres.*
—116·°	1·0	—112·°	1·0
— 28·6°	9·0	— 29·2°	12·7
— 9·4°	11·01	— 4°	19·93
+ 14°	17·06	+ 14°	26·76
32°	21·53	32°	35·40
41·45°	25·48	41°	40·47
56·3°	32·77	59°	52·17
67·27°	39.76	68°	58·84

The critical point of the gas has been placed by Ansdell at 98·69° F. He also determined the specific gravity of the liquefied gas at various temperatures, placing the density at about one-half that of carbon dioxide; but his results do not agree with those obtained by us in the production and storage of large quantities of the liquefied gas. For instance, the small tank to which this connecting pipe and burner are attached (*Fig. 2*) should contain, according to Ansdell, when filled at 69·08° F., about 2·15 pounds of liquefied acetylene; as a matter of fact, however, we can fill into this tank somewhat more than two and three-quarter pounds of the liquefied gas. We are now engaged in preparing a new table of pressures and specific gravities of the liquefied gas, and will be pleased to communicate the results to you at a later date. One pound of the liquid, when evaporated at 64° F., will produce fourteen and one-half cubic feet of gas at atmospheric pressure; or a volume 400 times larger than that of the liquid.

The odor of the gas has already been made apparent to you whilst the experiment showing the decomposition of the various carbides with water was being carried on. We will now show you the liquefied gas contained in this glass tube surrounded by a metal casing (*Fig. 3*). As you will observe, the liquefied gas forms a colorless, mobile, highly refractive liquid, which, when the pressure is slightly relieved, commences to boil and evolves a gas which, ignited as it issues from this gas tip, burns with an intensely white flame. If the liquefied gas be suddenly relieved of its pressure, or allowed to escape in its liquefied state to the atmosphere, a portion evaporates rapidly, thereby abstracting from the remaining portion sufficient heat to solidify it. This tank,

which is now shown you (*Fig. 4*), contains liquefied acetylene, which has been cooled to a temperature of —28° F., in order to prevent the escape of too large a volume of gas during the process of its solidification. Attached to this valve, inside of the tank, is a tube which reaches within half an inch of the tank bottom, and is open at its lower end. We now attach to the valve a flannel bag to receive the solidified gas. Upon opening the valve the liquefied gas escapes, the solidified portion remaining in the bag, while the gas formed escapes through the pores of the bag. This bag will hold about three-quarters of a pound of the solidified gas, and this is about the quantity which is now being emptied on the plate. A portion of this solidified gas will now be passed to you for inspection; another portion is packed into this wooden tube, a thermometer is inserted

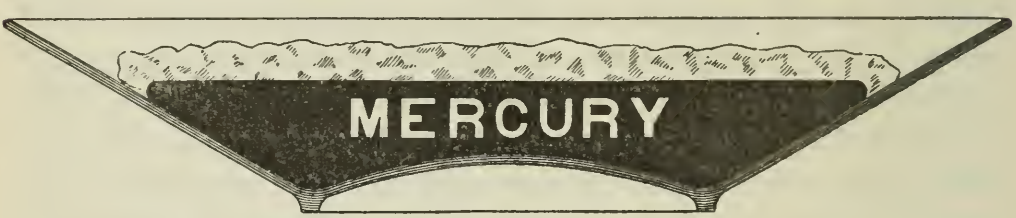

FIG 6.

(*Fig. 5*), and, as you will observe, the temperature falls to — 118° F. Another portion is placed on one pound of mercury contained in this saucer (*Fig. 6*); the intense cold of the solidified gas almost immediately solidifies the liquid metal. A portion of the solidified gas or "acetylene snow" is now dropped into this vessel (*Fig. 7*), containing water. Being lighter than water, it floats upon its surface, and when touched with a light the gas surrounding each particle of the solidified gas burns with a sooty flame, and continues to burn until all the solidified gas has disappeared. I will now ignite the gas evolving from the acetylene snow contained in this dish, and you have the interesting exhibit of a solidified gas at — 118° F., giving off gas which can be ignited, and which, although evolved at this low temperature, possesses the same illuminating power as at higher temperatures.

(*Willson and Suckert.*)

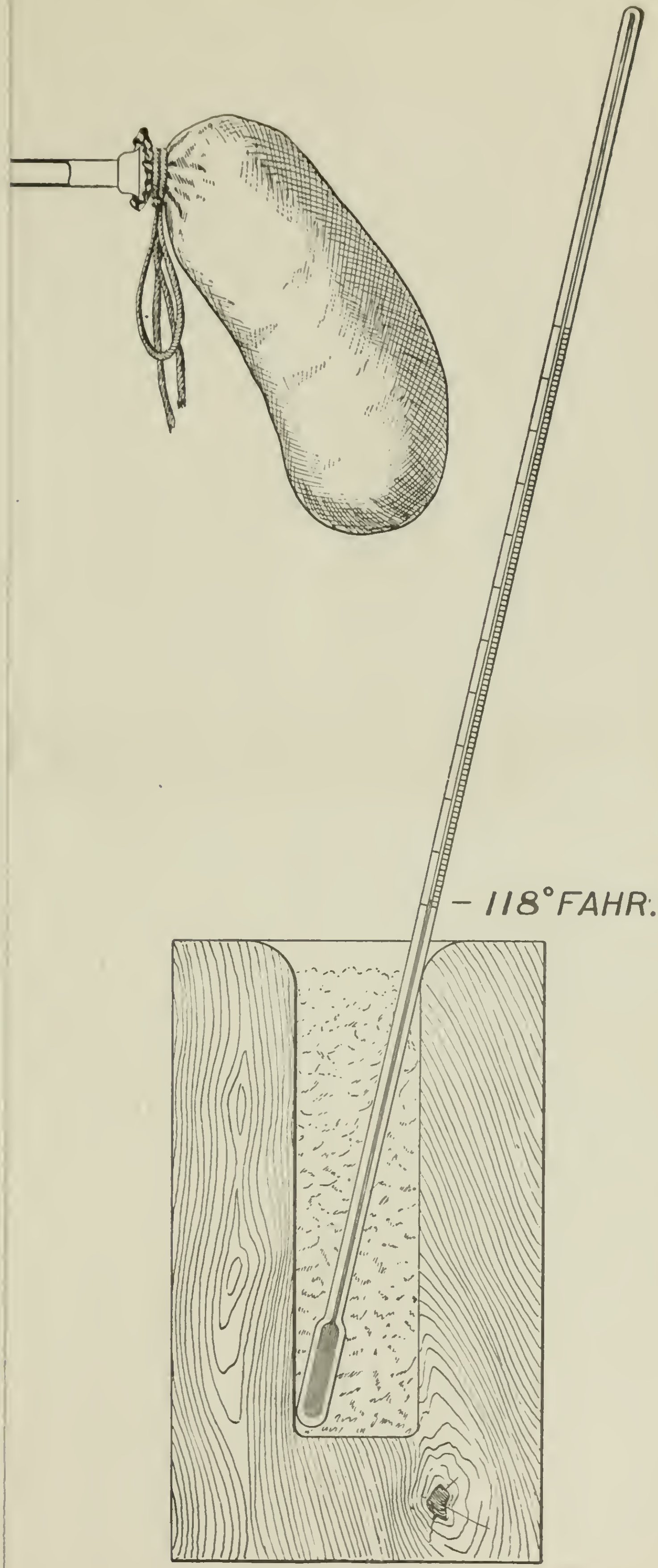

FIG. 5

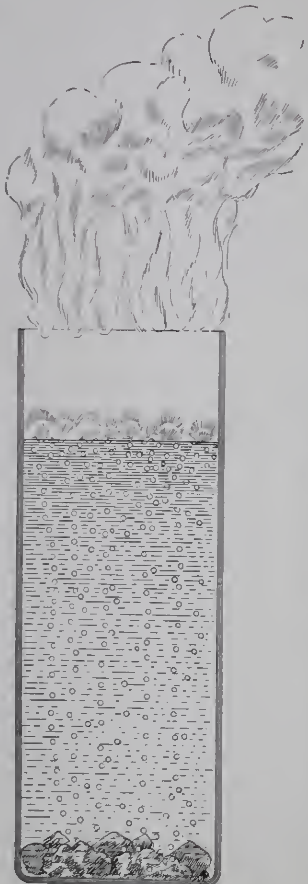

FIG. 1.

FIG. 2.

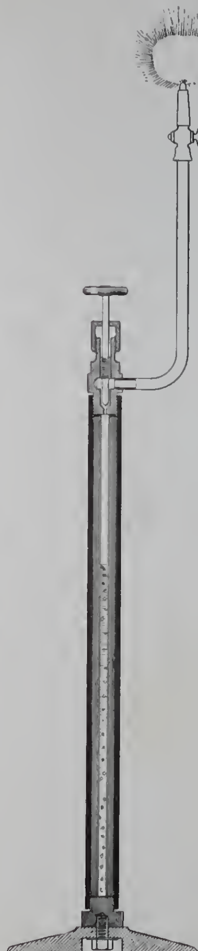

FIG. 3.

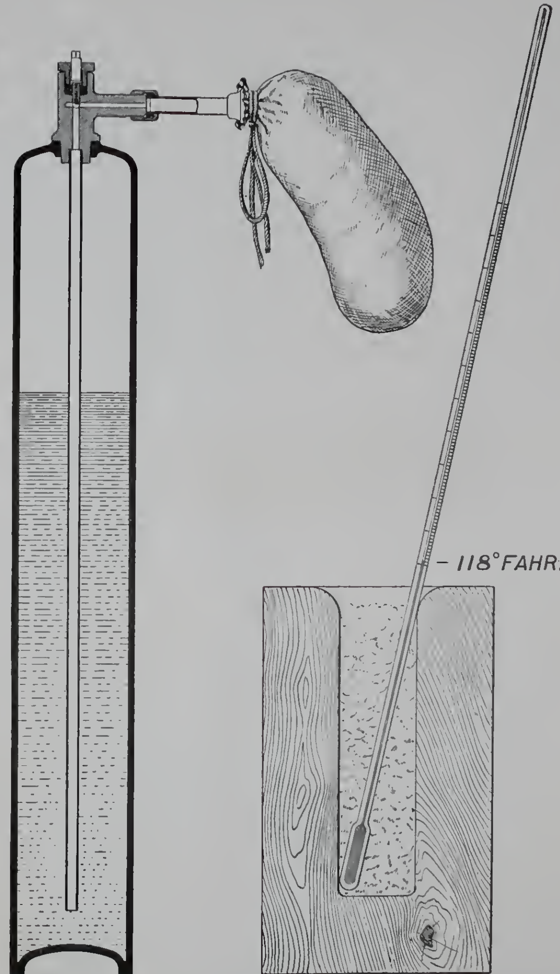

FIG. 4. FIG. 5

You have now seen acetylene in its three physical conditions, namely, as a gas, a liquid and a solid; and the mere fact that it readily assumes the gaseous and liquid condition is of vital importance to its commercial application.

COMMERCIAL APPLICATION.

Having described the physical and chemical properties of calcium carbide and the product of its decomposition with water—acetylene—we will now consider the commercial possibilities of these compounds.

FIG. 7.

Carbide of calcium, as we have already shown, is a rich source of acetylene, but beyond this we cannot at present definitely designate additional commercial applications of this material.

Extended experiments are now being conducted to determine its commercial value in the production of cyanides and various nitrogenous compounds, in the manufacture of iron, steel and other metals, and their alloys, and in its application to the synthetical formation of various organic compounds.

The results thus far obtained, however, although encour-

aging, do not as yet justify us in accepting them as commercially applicable.

As the commercial value of any material largely depends upon its cost of production, its purity, and the value of the products and by-products obtained therefrom, our first consideration will be the method of manufacturing the carbide of calcium and the cost of the finished product.

The carbide of calcium originally prepared by Mr. Willson during his first experiments was produced at a cost

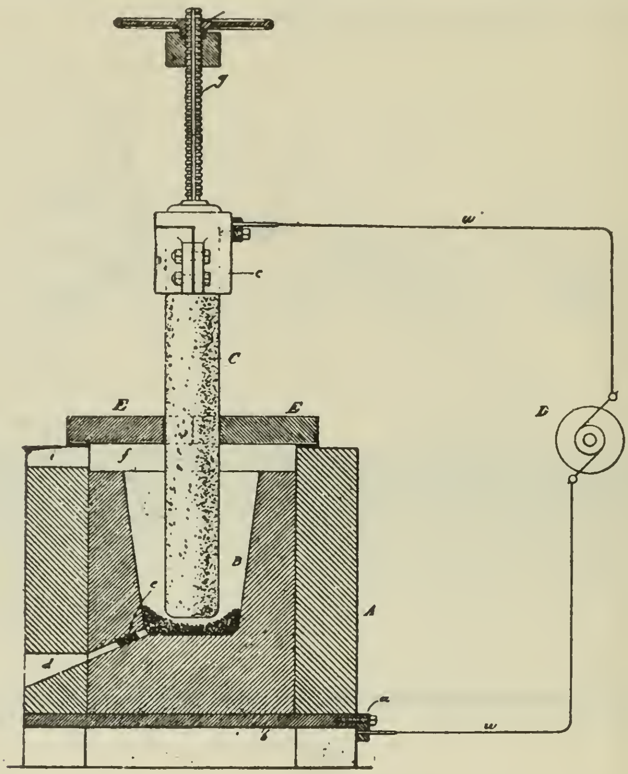

FIG. 8.

largely in excess of that for which it can be manufactured to-day, but a description of these original experiments will, without doubt, be of interest to you.

The first experiments were made with a dynamo generating a current of 150 ampères at from 60 to 70 volts. The furnace consisted of a plate of carbon 12 inches square and 1 inch in thickness, along one edge of which an iron rod was bolted and projected beyond the mason work, and to which one terminal from the dynamo was connected. This carbon plate was embedded in brickwork,

having only a small central portion exposed, upon which the graphite crucible rested. From one terminal of the dynamo, the current was conducted through the iron rod, carbon plate, graphite crucible, the material to be acted upon, and the carbon pencil, to the other terminal. To start the furnace, the pencil was placed in contact with the bottom of the crucible and the dynamo was started up slowly. As the electromotive force increased, the pencil was withdrawn from the bottom of the crucible and the "arc" established.

The material to be acted upon was then introduced through an opening in the cover of the crucible, the cover being either of non-conducting material, or, if of graphite, insulated from the crucible by a non-conducting luting. One of the pencils from the original lot used in these earlier experiments is now before you. This carbon pencil is 12 inches long, 1¼ inches in diameter, copper-plated and has a hole bored through its entire length, the tube so formed being used for the introduction of gaseous agents. With this furnace various metallic compounds, intermingled with pulverized carbon and also surrounded by gaseous reducing agents, were subjected to the intense heat developed by the electric arc.

The success attending the operation of this first furnace, in the reduction of refractory metallic oxides, justified the continuation of the experiments upon a larger scale, and to this end the Willson Aluminum Company was organized and a plant erected at Spray, N. C. This plant was supplied with a dynamo, operated by water-power, and generating a current of 2,000 ampères at 35 volts. The furnace was constructed as here shown (*Fig. 8*), namely:

A designates the outer masonry shed or bench of the furnace; *B*, the carbon or graphite crucible or hearth; *C*, the carbon bar or pencil constituting the movable electrode, and *D*, the dynamo for generating the current. From the terminal brushes of this dynamo, one wire, *w*, leads to and communicates with the crucible *B*, while the other wire, *w'*, leads to and communicates with the carbon pencil *C*. The connections are usually made in the manner shown,

the wire *w* being connected through a fastening-bar *a*, to an iron plate *b*, underlying the crucible *B*, and the wire *w'* being connected to a metal socket *c*, embracing the upper end of the carbon pencil *C*. The bench *A* is generally made of firebrick, which is a non-conductor of electricity, and the furnace is covered with a plate or, preferably, two plates, *EE*, of carbon, having a central hole, through which the carbon pencil *C* projects down into the crucible.

For tapping out the resulting product, a tap-hole *d* is formed which, in operation, is closed by a plug *e*, of clay or other suitable refractory material. The carbon plates *EE* rest on the top of the firebrick walls *A*, which project above the top of the crucible, forming an intervening space *f* for the furnace, between *B* and *E*. For the vertical adjustment of the carbon pencil a screw-threaded shaft *g* is provided, which may be moved up and down by the engagement therewith of a suitably-mounted rotative nut *h*.

The first carbide of calcium produced in this furnace, in accordance with memoranda taken at the time by Mr. Willson, was manufactured as follows: A mixture of lime and tar was boiled in a caldron, in the proportion of 60 pounds of lime to 11 gallons of coal-tar, and the heating was continued until the mixture was perfectly dry. It was then introduced into the furnace and subjected to the heat of the electric arc for a period of two hours, gradually feeding the mixture of lime and tar to the furnace as fusion took place. The product obtained consisted of a purplish-yellow mass, which, in contact with water, evolved acetylene gas. A sample of the calcium carbide produced upon this occasion is now before you, and represents the first calcium carbide produced in an electrical furnace.

The experiment was repeated with a mixture of 15 pounds of tar in fused lime and alumina, the time required for the operation being one and one-half hours.

The product obtained was a black, crystalline mass, consisting of a double carbide of calcium and aluminum. A sample of this double carbide is also submitted for your inspection.

Another run, made with a mixture of 10 pounds of lime and 10 pounds of finely-divided carbon, operating one hour,

resulted in the production of a dark, crystalline mass, showing at its fracture black and blue crystals. A small metallic ingot was found in this mass, and a similar ingot of this white metal is now before you.

A fourth test, made with $17\frac{1}{2}$ pounds of lime and $17\frac{1}{2}$ pounds of carbon, resulted in obtaining 11 pounds of almost pure calcium carbide.*

The tests described represent but a few of the numerous experiments conducted by Mr. Willson in his efforts to successfully and economically produce calcium carbide on a large scale. Recent results in the application of the alternating current to its manufacture prove conclusively that calcium carbide, of a remarkable purity, can be commercially produced. The product now being manufactured, in quantities exceeding one ton *per diem*, will readily evolve in contact with water $5\frac{3}{4}$ cubic feet of acetylene gas per pound of the carbide used, a result closely approaching to that which is theoretically possible, namely, $5\frac{89}{100}$ cubic feet per pound of carbide.

The theoretical proportions of lime and carbon required for the production of 100 pounds of calcium carbide are, $87\frac{1}{2}$ pounds of lime and $56\frac{1}{4}$ pounds of carbon. Of the latter $37\frac{1}{2}$ pounds combine directly with the metal calcium; and $18\frac{3}{4}$ pounds combine with the oxygen of the lime, and escape from the furnace as carbon monoxide, in accordance with the following formulæ:

$$
\begin{aligned}
CaO + C_3 &= CaC_2 + CO \\
87\tfrac{1}{2} + 56\tfrac{1}{4} &= 100 + 43\tfrac{3}{4}\ \text{(lbs.)} \\
CaC_2 &= Ca + C \\
100 &= 62\tfrac{1}{2} + 37\tfrac{1}{2}\ \text{(lbs.)} \\
CO &= C + O \\
43\tfrac{3}{4} &= 18\tfrac{3}{4} + 25\ \text{(lbs.)}
\end{aligned}
$$

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* A sample of the carbide obtained during this last test was sent by Mr. Willson to Lord Kelvin, of the Glasgow University, and, in return, the following reply was received:

"THE UNIVERSITY, GLASGOW, October 3, 1892.

"DEAR SIR:—I have seen and tried the calcium carbide, only, however, so far as throwing it into water and setting fire to the gas which comes off. It seems to me a most interesting substance and I thank you very much for sending it to me. Yours, very truly,

"KELVIN.

"THOMAS L. WILLSON, ESQ."

A further element of cost in its manufacture is the production of heat in the furnace by means of the electric arc. Extended experiments in this direction have shown that one electrical horse-power will readily produce twenty pounds of calcium carbide each twenty-four hours, and the present indications justify the assumption that with automatically-fed furnaces, properly insulated to retain the heat, and by utilizing the waste heat to increase the temperature of the material acted upon, the production of calcium carbide can be increased on a large scale to thirty pounds per electrical horse-power each twenty-four hours.

By using limestone and coal dust, the latter being practically a waste product (not at present utilized), it is believed that calcium carbide can eventually be produced at a cost of less than $5 per ton. Where bituminous coal is employed, the value of the by-products obtained by its conversion into coke will largely reduce the cost of manufacture.

The hydrate of lime obtained from the decomposition of the carbide with water can be used again in the manufacture of the carbide, or it can be employed in the manufacture of ready-mixed mortar, which is already quite an industry in this city.*

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* The following details of the cost of producing 150 tons of calcium carbide *per diem*, as a by-product in the manufacture of 100,000 fire- and pressed-brick *per diem*, will, no doubt, interest you.

The figures were compiled by a manufacturer who was desirous of commercially utilizing the close proximity of large deposits of coal, limestone and clay. They show an annual profit of $635,640, with a selling price of $7 per ton for carbide.

JANUARY 19, 1895.

PRODUCT OF 1,400 TONS OF COAL, 450 TONS OF CLAY AND 270 TONS OF LIMESTONE.

150 tons of calcium carbide, at $7	$1,050 00
10 tons of sulphate of ammonia, at $70	700 00
40 tons of coal tar, at $7	280 00
910 tons of coke, at 90 cents	819 00
50,000 fire brick at works at $15	750 00
50,000 dry pressed front brick, at $15	750 00
	$4,349 00

5,445,000 FEET OF RICH ILLUMINATING GAS.

3,240,000 feet of this will produce 12,000 horse-power for 24 hours, allowing 1¼ pounds coal per horse-power, and 9 cubic feet of gas as the equivalent

Arrangements are now being made by the Electro-Gas Company, of New York City, with the Niagara Falls Power Company, to apply 1,000 electrical horse-power to the manufacture of calcium carbide, which is shortly to be increased to 5,000 horse-power, and, eventually, we will, without a doubt, see the entire available power the company now possesses converted into electrical energy for the manufacture of this product. The effect of such a production would be far-reaching, and the economies resulting therefrom, if stated to-night, appear exaggerated and visionary. Assuming that but 20 pounds of the carbide are produced per indicated horse-power each 24 hours, then the amount manufactured during 300 working days would be 3 tons per horse-power per year; and, applying 100,000 horse-power to its production, the annual output of such an establishment would be 300,000 tons. From this amount of material 3,300,000,000 cubic feet of acetylene gas should be produced, and as its illuminating power, compared with ordinary illuminating gas of 25 candle-power, is as ten to one, it would

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of 1 pound of coal. 1,485,000 cubic feet of gas will burn 270 tons of limestone, producing 150 tons of lime, allowing 1,100 pounds of coal per ton of lime, and 9 cubic feet of gas as the equivalent of 1 pound of coal. 720,000 cubic feet of gas will burn 100,000 bricks, allowing 800 pounds of coal per 1,000 bricks.

Expenses :

Mining 1,400 tons of coal, at 55 cents		$770 00
Mining 450 tons of clay, at 35 cents		157 50
Mining 270 tons of limestone, at 25 cents		67 50
Labor on 1,000 tons of coke, at 20 cents		200 00
Freight on 210 tons of limestone, at 50 cents		135 00
Labor in grinding 150 tons of lime, at 25 cents		37 50
Labor in making 100,000 brick, at $2 per M		200 00
Labor in smelting calcium carbide		150 00
		$1,717 50
Twenty-five per cent. on $1,717.50 for general expenses		429 37
		$2,146 86
Interest on plant per day		83 33
		$2,230 20
Income	$4,349 00	
Expenses	2,230 20	
Net income per day	$2,118 80	
Net income per year (300 days)	$635,640 00	

represent fully 33,000,000,000 cubic feet of this gas—an amount which would probably equal the annual output of the entire gas industry of the United States.

As this is but one of the many applications of the product obtained by the decomposition of the carbide with water, the manufacture of the carbide itself must, of necessity, become a large industry.

As we have previously informed you, pure calcium carbide contains, in 100 parts, 37·5 parts of carbon and 62·5 parts of calcium, and when brought in contact with water, acetylene is generated to the extent of 5·89 cubic feet of the gas to each pound of carbide used; or if compared by weight, 100 pounds of calcium carbide and 56·25 pounds of water evolve 40·63 pounds of acetylene gas, and form 115·62 pounds of calcic hydrate, in accordance with the following formula:

$$CaC_2 + 2H_2O = CaOH_2O + C_2H_2$$
$$100 + 56{\cdot}25 = 115{\cdot}62 + 40{\cdot}625 \text{ (pounds.)}$$

The acetylene gas so generated contains, in 100 parts, 92·3 parts of carbon and 7·7 parts of hydrogen, or in the 40·625 pounds generated from 100 pounds of carbide, we have 37½ pounds of carbon and 3⅛ pounds of hydrogen. The entire carbon contained in the calcium carbide has, therefore, combined with the hydrogen of the decomposed water to form a new compound of a gaseous nature and extremely rich in carbon.

In its commercial application acetylene can be produced either directly from the calcium carbide by decomposition with water, or it may be evolved from the liquefied gas contained in suitable receivers.

When manufactured directly from the carbide, two methods can be employed; in one, small quantities of water are allowed to flow upon the carbide and the resulting gas is conducted to an ordinary gasometer, from which it can be drawn for use; this method is more or less intermittent. The other method dispenses with a gasometer and permits the continuous generation of either large or small quantities of the gas, and this is accomplished by partially sub-

merging in water a vessel, open at the bottom and containing carbide suspended on a screen in the upper part of the vessel, the generated gas being withdrawn from above the carbide. As long as gas is being used the water remains more or less in contact with the carbide; as soon, however, as the withdrawal of gas diminishes or entirely ceases, the pressure of the generated gas forces the water from the carbide into the lower chamber of the vessel, thereby preventing a further generation of the gas. The apparatus is automatic and extremely regular in its operation.

In the employment of either of the above methods, the only by-product obtained is slaked lime, the amount of gas produced being the same, namely, 5½ cubic feet for each pound of calcium carbide used.

The liquefied gas is manufactured commercially by decomposing the carbide of calcium with water in a closed vessel, and conducting the gas generated under pressure to a condenser, where it liquefies and is then drawn off in tanks ready for distribution.* The liquefied gas, exhibited this evening, has been produced in this manner.

Before entering upon the use of acetylene as an illuminant, we desire to call your attention to the fact that its rapid and extraordinary development in this direction is largely due to the individual efforts of Mr. E. N. Dickerson, of New York City, who, endowed with a special knowledge of the subject, has labored unceasingly to bring about the successful result which you will see this evening.

As an illuminant, acetylene surpasses in lighting power and economy all other illuminants known; when burned at the rate of five cubic feet per hour, it produces a light equal to 250 candles, whereas the best illuminating gas made from coal, or water gas, rarely exceeds twenty-two candles for each five cubic feet burned per hour. Your Philadelphia city gas is rated at from nineteen to twenty candles. Acetylene gas will, therefore, produce twelve and one-half times more light if the same quantity be consumed, or, 1,000 cubic feet of acetylene gas will give you the equivalent in

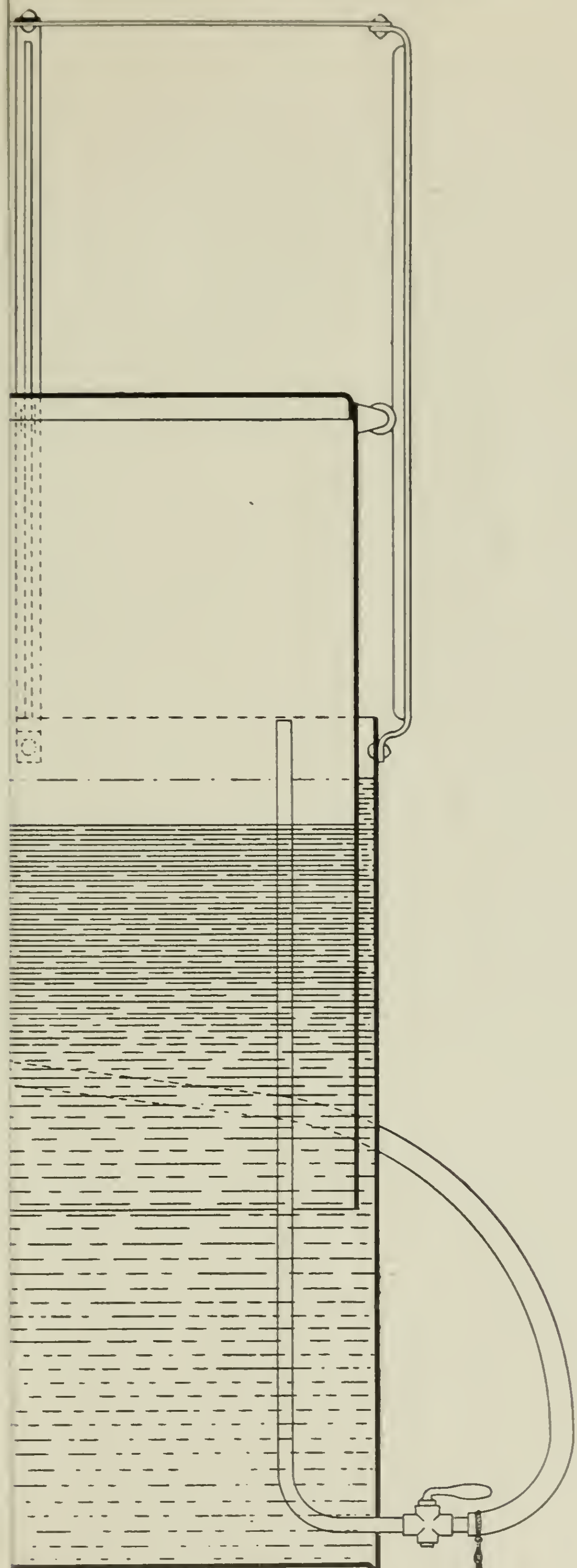
* A full description of this process and of the apparatus required therefor, is contained in U. S. Patent, No. 535,944, March 19, 1895.

lighting power of 12,500 cubic feet of your city gas; it has, therefore, twelve and one-half times the value. To illustrate more fully the difference, we will first pass your city gas to the tube attached to this stand, and ignite the gas as it issues from the burners; we then conduct acetylene gas to a similar row of burners, and light these; the contrast, as you will perceive, is almost marvelous.

The acetylene consumed in these burners has been generated, in the apparatus before you, in the following manner: Upon the carbide contained in this closed jar (*Fig. 9*), water is poured in small quantities through the glass funnel communicating with the interior of the jar. The acetylene gas generated passes through this tube to the inside of the gasometer, thereby lifting the holder to the position which it now occupies, and the gas can then be conducted from the holder to the burners by means of this rubber tube. As the gas is being consumed and the holder lowers, the supply is rapidly renewed by pouring an additional amount of water through the funnel upon the carbide contained in the closed jar. We will also light the gas produced from liquefied acetylene contained in this small tank (*Fig. 10*), and, as you observe, it burns with the same brilliancy and lighting power as the gas produced directly from the carbide.

The liquefied gas contained in the small tank weighs just two pounds, and is capable of generating twenty-nine cubic feet of acetylene gas, which is at the rate of fourteen and one-half cubic feet per pound. The gas produced by the vaporization of the liquid at a pressure, as the gauge now indicates, of forty atmospheres, passes from the tank to a reducing valve upon which the tank stands, whereby its pressure is reduced to that of a two-inch water column, as indicated on this **U** water gauge, and it is under this pressure that we are supplying the gas to the burners attached to the arm above. Each of the burners supplied with acetylene gas will consume, at the pressure indicated, $1\frac{2}{10}$ cubic feet per hour, each, therefore, emits a light equal to sixty candle-power; the total candle-power of the six burners in use is, therefore, 360, and the amount of gas consumed each hour $7\frac{2}{10}$ cubic feet. To obtain this result with city gas

(*Willson and Suckert.*)



I Calcium Carbide.

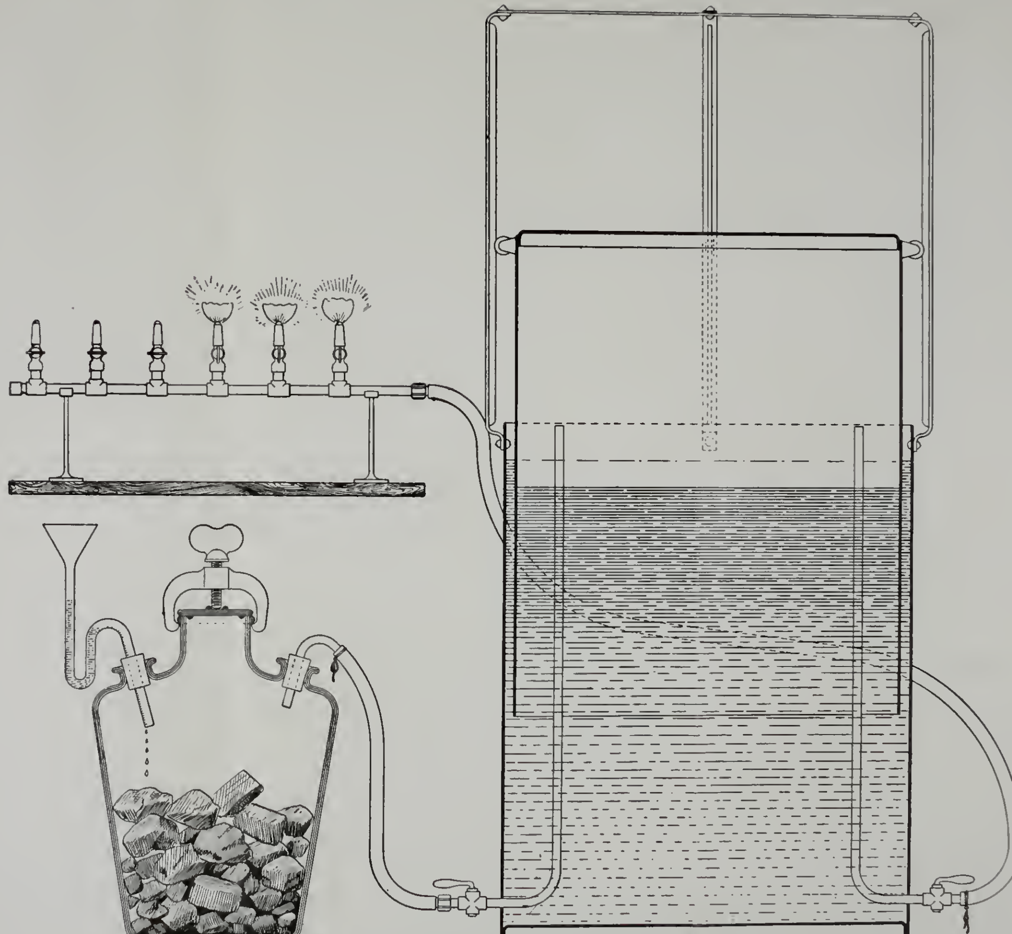


Fig. 9.—Apparatus for the Manufacture of Acetylene from Calcium Carbide.

would require the consumption of at least ninety cubic feet per hour.

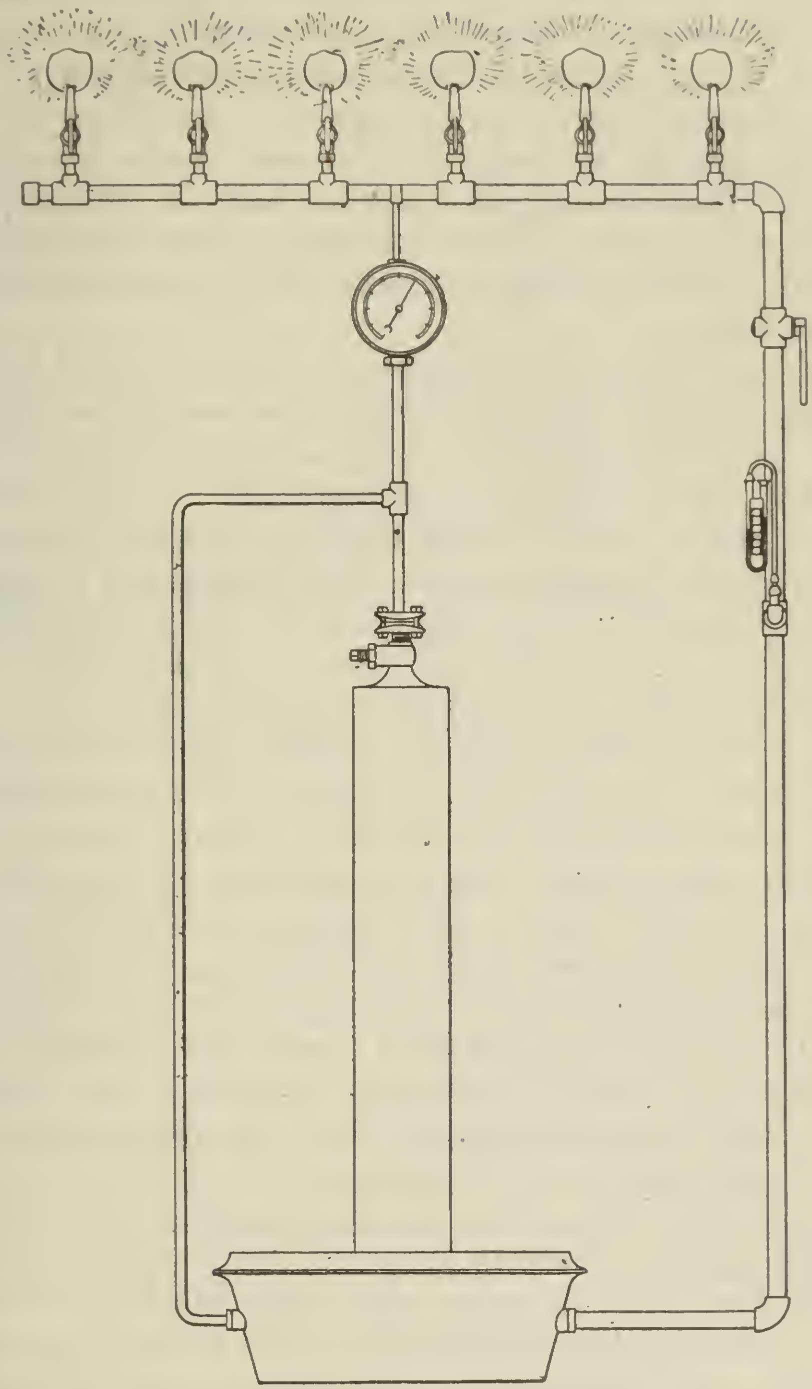


FIG. 10.

The amount of oxygen withdrawn from the atmosphere of this room by the acetylene for the same amount of light, is but one-sixth of that required for your city gas; the

products of combustion are, therefore, reduced in proportion and the air of the room is not vitiated to the same extent.

From the appearance of the acetylene flame it would seem as though its temperature was exceedingly high; but recent determinations have shown that the temperature of the flame does not exceed 900° C., whereas the temperature of ordinary illuminating gas exceeds 1,400° C. For an equal amount of light the heat developed by the combustion of acetylene gas but slightly exceeds that of the incandescent electric lamp.

We have before us to-night, therefore, an ideal illuminating gas; its presence in a room can readily be detected by its penetrating odor; it emits more light with less heat than any other illuminating compound; it consumes less oxygen, and it can be commercially produced at less cost, for an equal amount of light. Furthermore, it is capable of being stored either as a solid, in the form of carbide, or as a gas, or as a liquid; and these qualities alone are of exceptional value in its commercial application.

As a solid, in the form of carbide, waste water-power throughout the world can be utilized for its manufacture, and it can be shipped long distances without material deterioration. As a gas, it can be generated from carbide and applied as such; and in the form of a liquid, it can be applied to all purposes of isolated lighting, such as railroad and street cars, carriages, bicycles, steamships, sailing vessels, street lighting (by placing a small tank in each lamppost (see *Fig. 2*), house lighting (in both city and country), buoys, lighthouses, lanterns, and to the enriching of ordinary illuminating gas in dwellings. Its application to this latter purpose will permit the gas companies to produce a low-priced gas for heating purposes, which can then readily be enriched in each house with acetylene gas generated from a tank of the liquefied gas. To show the value of acetylene gas if applied to the lighting of your city, we will make a comparison, which may surprise you. The amount of gas produced by your city works will approximate 4,000,000,000 cubic feet per year, of, say, twenty candle-power. By the use of acetylene gas, the amount of gas required

would be reduced in the proportion of 1 to 12·5; or, 4,000,000,-000 cubic feet of city gas could be replaced by 320,000,000 cubic feet acetylene gas, representing a saving of 3,680,000,-000 cubic feet of gas annually.

In addition to its value as an illuminant, acetylene gas can be used commercially for power and heating purposes; and in the form of a liquefied gas it will be invaluable for such use. Its application in this direction is, however, such an extensive one that we are compelled to make it the subject matter of another paper. In conclusion, we desire to thank you all for your kind attention, and especially the officers and members of the Franklin Institute, for the interest they have manifested in our work.

THE NATURAL SODA DEPOSITS OF THE UNITED STATES.*

By Dr. Thos. M. Chatard.

[*Concluded from p. 283.*]

About two miles northeast from Ragtown one may notice a slight elevation on the surface of the desert, but the ascent is so gentle that one can hardly appreciate it. Suddenly, and without preparation, one comes upon the brink of a precipitous depression in the desert, more than 300 acres in area, the rim being more than 150 feet above the surface of the lake, which covers the greater part of the bottom of the cavity. The shores of this lake are lined with the vats of the soda-makers, whose white houses make a pretty contrast with the green salt grass and the blue waters of the lake. Flocks of small birds are continually hovering over the lake, and the whole presents a scene of life and color, the more beautiful because unexpected and in sudden contrast to the burning sand without, where beauty is represented by the horned toad and life by the tarantula.

* A lecture delivered before the Franklin Institute, February 23, 1894.

An eighth of a mile away, and separated by a narrow ridge, is another depression similar to the first, and called the Little Lake. While less attractive, it is quite as interesting; perhaps even more so.

Both of these depressions are evidently the craters of extinct volcanoes. The walls are composed of loose, sandy materials intermixed with pieces of rock, often two or three feet in diameter, and which are evidently volcanic ashes with larger masses of scoria. The deepest place in the lake is 312 feet below the highest part of the rim, and, as the surface of the water lies many feet below the bed of the neighboring Carson River, it is evident that these lakes, which have no apparent feeders and no outlets, are supplied by seepage from the river.

The water of the Big Lake is a strong solution of salts, mainly common salt, but with a large proportion of sulphate and of the two carbonates. You will remember that I have already told you that natural soda is composed of sodium monocarbonate and bicarbonate, with varying proportions of other salts, mainly chlorides and sulphates. Now I wish to impress upon you that, in nature, these two carbonates are always found together, and, furthermore, that if one exposes the solution of pure monocarbonate to the action of the air, the solution absorbs carbonic acid and a portion of the monocarbonate is converted into bicarbonate. The presence of the carbonate in this water must be accounted for by the decomposition of the volcanic ash through the action of air and moisture, as already described, the soluble salts thus formed being leached out of the mass by the river seepage, conveyed to the crater, and then concentrated by evaporation. The change of the monocarbonate into bicarbonate is continually going on, but appears to pause whenever the relation between the two salts reaches a certain limit, and the phenomenon is most important, as it gives us the only means of extracting the valuable carbonates from the accompanying useless salts.

For many years past the extraction of sodium carbonate from the waters of the Big Lake has been an established industry. The method is ingenious, and although, because

of natural disadvantages, the annual production is small, the work done here has yielded much valuable practical information which is now being utilized on a larger scale at Owens Lake in California. As this latter place must be described later, we will not linger at the Big Lake, but pass to its companion, where we shall see an operation which is singular of its kind.

The Little Lake, which gave its name to the smaller crater, has been completely altered in appearance. There are four large, irregular-shaped excavations, besides a shallow pool of fresh water from small springs which issue from the sides of the crater. Two of these excavations are situated upon the ledge, which is a natural deposit of crystal soda, of unknown but considerable extent and thickness. These lye pits are filled from the pool with water, which gradually becomes saturated with the soda dissolved from the ledge. The liquid from the lye pits is drawn off from time to time into the crystallizers, as the other excavations are called. By the end of the summer the crystallizers are filled with a saturated solution of soda, which, during the winter, crystallizes out as the ordinary crystal soda. When no more crystals appear to form, by which time the deposit is ten or twelve inches thick, the crop is gathered, and carefully stacked, preparatory to the drying process, which is the most delicate part of the work. Soda crystal contains sixty-three per cent. of water and parts with most of it with great ease and rapidity, so that if heated to 90° F., a temperature much below the ordinary summer heat of the region, it melts in its own water of crystallization and becomes a liquid. In drying the crop, great care must, therefore, be exercised, lest the material becomes liquid, and much of it thereby lost.

The crop is, therefore, kept in the stacks until the approach of warm weather, when it is broken up and spread in a layer two or three inches deep, on drying floors, which are covered with light sheds open at the sides. The material is turned over from time to time. When the drying is completed, the product is a thoroughly effloresced, white powder; the annual product is about 300 tons.

Returning to Wadsworth, we can then strike in a northwestwardly direction through the region known as the Black Rock Desert, which, in summer, is a succession of alkali flats containing much soda, and in winter, an almost impassable morass. This extends almost up to the border of Oregon, in the southern portion of which State lie Abert and Summer Lakes, which, though now inaccessible, must in time become valuable, since in their waters the proportion of sulphate, which is very deleterious to the quality of the soda, and must, therefore, be kept out as much as possible in the extraction process, is smaller than in any other large source of natural soda that is known.

Leaving the Central Pacific Railroad, at Reno, Nev., we can go southward by the Virginia and Trucker Railroad, and the Carson and Colorado to Hawthorne, Nev., where we can reach Mono Lake, near Bodie, Mono County, Cal.

This is a large lake, covering 85 square miles, with an average depth of 60 feet, and lies in a region of fine scenery; but, as to its future, I can only repeat what I have elsewhere said, "that this large body of water, of a composition so favorable to utilization, is for practical purposes inaccessible, and that the high altitude and consequent shortness of the evaporating season would, under any circumstances, render the success of any industry established there very doubtful."

Proceeding southward from Mono Lake, we pass over a highly volcanic country and reach Long Valley, in which the Owens River originates. This valley is full of alkali flats, morasses and pools, the alkali being, as before, derived from the decomposition of the volcanic rocks, a process which is now going on and can everywhere be observed. The drainage of the valley is by the Owens River, a stream which carries a considerable amount of alkali, all of which finally reaches Owens Lake, Inyo County, Cal.

This lake is the most important occurrence of natural soda in the world. Its area is even greater than Mono Lake, being over 100 square miles, with an average depth of not less than 17 feet. It is readily accessible, as the Carson and Colorado Railroad runs along the eastern shore, and can easily be reached by all of the great continental lines.

The lake lies between the Sierra Nevada on the west, and the Inyo Range on the east, and has no outlet, the lowest point of the rim of the valley being, as I am informed, about fifty feet higher than the present level of the lake. On the western side, several small brooks from the Sierra make their way into the lake, but the larger portion of the water supply comes from the Owens River, which empties into the lake at its northern end. This stream was, in February, 1892, about 59 feet wide, 5½ feet deep, and had a flow of about 3 miles an hour. These measurements represent a considerable amount of water, but represent probably not more than two-thirds of the daily supply; and one gets some idea of the aridity of the climate, and of the rapidity of evaporation, when one remembers that although the lake is naturally somewhat higher in the spring than in the autumn, the average depth suffers but little change. Hence, at present the evaporation from its surface seems to be about equal to the amount of water received from all sources. As the valley lies between two high ranges of mountains, and is open to the north and south, there is usually a good breeze through the greater part of the twenty-four hours, thus much increasing the evaporation, which may safely be taken as over five feet per annum.

The Sierras rise rapidly from the lake, and the peaks are very lofty. Mt. Whitney, which is in plain view, is the highest mountain in the United States. They are well timbered, and their vast, sombre masses form an agreeable contrast to the opposite glaring, light colored Inyo Range, which is almost destitute of either wood or water.

Between the Inyo Range and the lake, the valley slopes gently from the foothills to the water edge, affording excellent locations for manufacturing purposes. The shore is covered in most places with a strong growth of salt grass, though there are extensive flats, which are bare.

In the lake itself are large quantities of a sort of "algous or fungoid plant, floating in globular masses of a whitish or yellowish green" (Loew). This collects upon the water in patches, and becomes black with the clouds of alkali flies or ephydra, which settle upon it. In addition to the larvæ

of these flies the water swarms with the little "alkali shrimp," or artemia. Both of these forms of animal life seem to be inseparable from alkali pools, being found in almost every one of them throughout the world.

The scenery of this valley is very attractive, and the soil, wherever irrigated, has proved itself to be very fertile. Very little snow falls in winter, and work can be done throughout the year. Even in summer, although the thermometer shows a high degree of heat, this is not oppressive, because of the dryness of the air, and sunstroke is, I believe, unknown. The highest temperature I have ever noted, the thermometer being in an exceptionally well-shaded place, was 109° F. Hot as this may seem, I spent the entire day at work in the sun with no protection and with no inconvenience, nor did any of the men working around me make any complaint. Indeed, a wilted collar is an impossibility in such a climate, as perspiration evaporates as fast as formed, and it is only necessary to drink a reasonable amount of water, and that not too cold, to have a far more comfortable time than is given to us by our Eastern summers. What is said of Owens Valley is true of the entire western side of the Great Basin, and whatever you may hear of the hardships that travellers may undergo, rest assured that those who are acquainted with the region find our Eastern climate much inferior.

At the village of Keeler, the terminus of the Carson and the Colorado Railroad, on the eastern side of the lake, are the works of the Inyo Development Company, which has been extracting soda from the lake waters since 1886, and is gradually developing a valuable industry. So far the company has confined its operations to supplying the wants of the borax makers along the line of the railroad, but can at any time speedily expand its operations to produce large amounts of high-grade soda ash.

The composition of the waters of Owens Lake is typical of all of the lakes which we have now hurriedly visited, and the method of extraction here employed is applicable to all of them in both its present stage of development and its future possibilities. We have, therefore, reached the point

where we can consider what this water is and how its valuable constituents can be utilized. I am not going to weary you with columns of analyses, or with technical details, for all these things have been published and can be read; but will try to give you a broad view of the whole subject, for in that way you will be able to form a much better idea of the greatness of the future.

I have told you that the waters of these lakes contain, as their principal constituents, sodium salts (mainly chloride, sulphate, carbonate and bicarbonate), together with some borax and some potassium salts. Of these salts only the carbonate and bicarbonate have any prospective value. These waters have all been carefully and repeatedly analyzed, and the area and depth of Abert, Mono and Owens Lakes fairly well determined. The amount of the two carbonates in each of these lakes can, therefore, be calculated, and the results are as follows:

Abert Lake has an area of 40 square miles and an average depth of 10 feet; Mono Lake, 85 square miles and depth of 60 feet; and Owens Lake, over 100 square miles, average depth 17 feet.

Taking these areas and depths, and knowing the amount of each salt in a given volume of the water, we obtain for the number of tons of carbonate and bicarbonate in these lakes the following surprising figures:

	Sod. Carb., Tons.		*Sod. Bicarb, Tons.*	
Abert Lake, . .	3,428,352	(3½ millions).	1,560,000	(1½ millions).
Mono Lake, .	75,072,000	(75 "	17,936,000	(18 "
Owens Lake, .	39,875,200	(40 "	8,431,000	(8½ "
Total,	118,375,552	(118 millions).	27,927,000	(28 millions).

Vast as this amount may seem, we must not forget that we are considering but three localities, leaving out the Ragtown Lakes, Summer Lake, the Black Rock Desert, Long Valley and many other places, which probably aggregate a far larger amount. It is, therefore, no exaggeration to say that within a belt of country fifty miles wide and extending from Abert Lake, in southern Oregon, to Owens Lake, in southeastern California, the amount of sodium car-

bonate, in the form of dry deposits, or of strong solutions, is more than sufficient to make 250,000,000 tons of soda ash.

Now, no one who knows that country, will doubt these figures; but for all that, some hard-headed man of business in this audience is probably talking to himself thus:

"I have no doubt of it. I am also well aware that unlimited quantities of a very superior quality of ice exists at the North Pole, but I am quite sure that ice will not be any cheaper in Philadelphia next summer for that reason. I have also been told that all sea water contains gold, but have never heard of any one getting rich from sea water unless he was a pirate or a hotel keeper."

Our friend is quite right. However lavish Nature may be, her gifts are wasted unless she so bestows them that they can be used by man. Most of these localities are at present inaccessible, and it may never be possible to make use of Mono Lake and of many of the smaller localities; but I feel that I am not exaggerating when I say that, at Owens Lake alone, there are space and facilities for works large enough to produce 250,000 tons of soda ash yearly, or the present annual consumption of the United States. Moreover, by a small addition to the present railroad facilities, this entire amount can be profitably made and distributed at present prices. Remembering also how much soda already exists in the lake, and that the latter is continually receiving additions through drainage, you will see that even this large production could only slowly reduce the supply.

It now remains to show you how this work can be done. The fundamental principles of a correct extraction process are these: The solubility of sodium bicarbonate is much less than that of either sulphate, chloride or the ordinary carbonate. At the ordinary temperature of 60° F., 100 parts of water dissolve 36 parts of sodium chloride, 16 parts of sodium carbonate, 13 parts of sulphate, and less than 9 parts of bicarbonate. With rise of temperature the solubility of sodium carbonate and of sulphate increases greatly, so that, at the summer temperature of 90° F., 100 parts of water can dissolve 46 parts of carbonate, or 50 parts of sulphate, but only 11 parts of bicarbonate. The solubility of bicarbonate

is also much diminished if chloride or sulphate is also present in the solution. If a solution containing equal parts of sodium chloride and bicarbonate is allowed to evaporate, it will be found that almost all of the bicarbonate will crystallize before the chloride begins to deposit, and the same is the case if sulphate is substituted for the chloride, though the separation is not so sharply defined.

Now, if sodium carbonate is also present in such a solution, the bicarbonate, in depositing, takes with it a certain definite proportion of carbonate, and forms with it a well-crystallized salt of definite composition. This double salt has long been known to mineralogists under the name of "urao," but its importance in the technology of natural soda has only lately been recognized. Upon the properties of this salt depends the entire process by which high-grade soda ash can be made from the impure natural soda. We will, however, call it "summer soda," the name given to it at the Big Lake at Ragtown, and at Owens Lake, where it is the product of the crystallizing vats.

When the solution of natural soda, such as the water of any of these lakes, is allowed to evaporate at any temperature below 150° F., a crop of crystals will be obtained. The crystals are colorless needles or prisms, and, if the evaporation is not pushed too far, will be practically free from sulphate or chloride. The composition is quite constant, and the salt may be considered as made up of 47 parts of sodium carbonate, 37 parts of bicarbonate, and 16 parts of water of crystallization. If a solution contains monocarbonate, sulphate and chloride, but no bicarbonate, it will be difficult to separate the carbonate from the other salts; but if bicarbonate is present, this will separate first, and, in depositing, every 37 parts will take with them 47 parts of carbonate. In this way we are able to extract from such a solution a very large proportion of its valuable constituents, the other salts remaining in the mother liquor.

When this "summer soda" is heated to a temperature not much above 300° F., it readily parts with its water and the excess of carbonic acid belonging to the bicarbonate, and the residue is a compact "soda ash" or sodium carbon-

ate. It is therefore apparent that, to make a good soda ash from natural soda, is a very simple matter. Of course, to produce the largest possible amount from a given quantity of raw material, and to do this in an economical manner, involves a great many other considerations and a thorough technical training, but such details are foreign to this evening's purpose.

I may, however, say here that the carbonic acid which is given off in the process of converting this summer soda into soda ash must be utilized as closely as practicable in any rational manufacturing method, and this can be done by absorbing it in the raw solution, thus increasing the proportion of bicarbonate and the consequent yield of summer soda. If the carbonation of the raw solution be pushed far enough, almost all of the carbonate can be converted into bicarbonate and thus be separated in one operation. This, indeed, will occasionally be found advisable in practice, but the greater part of the ash will always be made from summer soda obtained by spontaneous crystallization, for which the hot and arid climate of the region is especially favorable, and enables the soda-maker to do his work with the minimum expenditure of fuel. In such a region, fuel will always be an expensive item, and manual labor will be scarce and, consequently, costly. The use of labor-saving devices and machinery naturally suggests itself, but will be limited by the cost of the necessary motive power, although any extra expense for this will probably be covered by greater efficiency in work and greater uniformity of product. The forms of machinery and furnaces used in the other soda processes are not suitable for this industry, though the principles can be applied with substantial modifications in design. The furnace temperatures are low, and thus fuel is saved; but careful management is necessary, and the furnace must be continuous and nearly automatic. The utilization of the furnace gases and the economical handling, packing, shipping, transporting and marketing of the products, present many interesting problems which may have to be solved by novel devices and arrangements. In general, the distance to the ultimate market will be great, and every saving will be necessary.

In conclusion, I can only repeat what I have said upon another occasion: "It would seem that the time must soon come when these vast natural resources will attract the serious attention of capital and business enterprise. The path is open. The general chemical lines are already well known, and the engineering problems, while numerous, are neither very complex nor very difficult. With the steady development of the transportation facilities of the far West, it may reasonably be expected that those arid regions will soon become the seat of a new, great and prosperous industry.

RECENT ADVANCES IN ELECTRO-CHEMISTRY.*

BY JOSEPH W. RICHARDS, A.C., PH.D.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Electro-chemistry is that division of chemical science which treats of the mutual relations of the electrical and chemical forces; it discusses the electrical effects of chemical action and the chemical effects of electrical action. This field has received a due share of attention in the century which has elapsed since it was opened to cultivation, but it is only within very recent years that its immense expansion, in both applied and theoretical aspects, has lifted it into the position of a distinct science.

To be qualified as an electro-chemist, the scientist must, first of all, be a chemist, knowing all that is implied by that term; and in addition to this, he must also be well informed in applied and theoretical electricity. But men thus qualified are few in number. Chemists generally have a smattering of electricity; electricians, as a class, know less about chemistry, so that the scientist who is

* A lecture delivered before the Franklin Institute, February 1, 1895.

master in both sciences may be termed a *rara avis*. Nearly all electro-chemical processes can be carried on only by the practical chemist, while the electrician plays a subordinate role.

The rapidly-growing importance of the applications of electro-chemistry has created a need for educated electro-chemists, with the above-described qualifications. The universities are looked to as able, if they will, to supply the want; and, in response, we note the establishment, within the last few years, of separate departments of electro-chemistry, with a professor at the head devoting all his attention to that subject. At Leipzig, Dr. Ostwald; at Göttingen, Dr. Nernst; at Aachen, Dr. Classen; at Hanover, Dr. Kohlrausch; in Berlin, Professor Slaby and Dr. Vogel; in Munich, Prof. W. von Miller; in Darmstadt, Professor Kittler; in Amsterdam, Professor van 't Hoff; in Münster, Professor Hittorf; in Paris, Moissan. In the United States, Johns Hopkins University has under consideration the establishment of a chair of electro-chemistry, and will probably take the lead in this direction, as it has done in so many other useful innovations; and it is to be hoped that in the present brilliant plans for the extension of post-graduate study at the University of Pennsylvania, this promising field will not be overlooked.

In Germany, interest in electro-chemistry has become so general that the German Electro-Chemical Society (*Deutsche Elektrochemische Gesellschaft*) was organized in 1894. Sixty-five scientists signed the call for a meeting, which was held in Cassel on the 21st of April, when the society was duly organized. Dr. Ostwald was chosen first president, and what promises to become a most flourishing society was started with great enthusiasm. The first yearly meeting was held in Berlin, on October 5th and 6th, 1894. Bunsen, Kohlrausch, Hittorf and Wiedemann, the lights of electro-chemical science in Germany, were named honorary members. Ostwald delivered an able address on "Johann Wilhelm Ritter, the Founder of Electro-chemistry," and a number of other important papers were read and discussed. At the close of 1894, the society already numbered 290 mem-

bers, among whom were enrolled about a score of interested participants from this side of the ocean.

Within the past year there has also been founded at least one journal devoted exclusively to this new science, and three others which devote particular attention to it. The *Elektrochemische Zeitschrift*, a monthly journal, made its first appearance in April, 1894. It is published in Berlin, and has the co-operation of most of the prominent electro-chemists in Europe.

About the middle of the same month, the *Zeitschrift für Elektrotechnik und Elektrochemie* made its first appearance in Halle, and is now published semi-monthly. This journal, as its name indicates, gives equal attention also to electro-technics in general. It has been chosen as the official organ of the German Electro-chemical Society. The *Aluminum World*, published monthly in New York, since September, 1894, devotes special attention to electro-metallurgy, one of the most important branches of electro-chemistry. *L'Aluminium: Journal de L'Electrolysé*, is a journal of similar range, published monthly in Paris, and which has made its first appearance within a month (January 3d). With such exceptionally favorable facilities for spreading information in the German, French and English languages, not to speak of a host of other journals of chemistry, metallurgy and electricity, eager to reprint each item of value, every advance in electro-chemistry is sure of being at once made known to the industrial and scientific world.

If inquiry be made as to any recently-published standard books on electro-chemistry, it must be said that there is none which covers the whole ground. Ostwald's "*Elektrochemie—Ihre Geschichte und Lehre*" is in course of publication, but it treats of the purely scientific side of the subject. Dr. Gore's "Electric Separation of Metals" is the best work in English on electro-metallurgy; while Dr. Borcher's "*Elektrometallurgie*" gives a still more recent review of that part of the field, in German. In French, Tomassi's unwieldy volume, "*D'Électroçhimie*," is a compilation of much valuable information thrown together in a rather disjointed way, but the reader will find recorded in it many

out-of-the-way facts which have escaped the other writers. Yet, many of the subjects which will be spoken of to-night are of so recent development that they have not yet found their way into the books, and allusion to them can be found only in the journals above mentioned. As the limits of a single lecture will only allow of a brief allusion to many interesting subjects, I give in each case references to the journals, which any one interested may consult for further information.

Electro-chemical Analysis.—Classen* has made a noteworthy contribution to this elegant method of analysis, by an exhaustive review of all his methods, giving in each case the concentration of bath, voltage, current density, temperature, etc., for best working. Such data were long needed, and this very thorough memoir marks an epoch in the history of electro-chemical analysis.

Batteries.—An entire evening would be necessary to describe all the newly-invented batteries. One, however, deserves special mention because of its applicability to electro-chemical experiments requiring high voltage. Warren† describes a cell, consisting of magnesium in a solution of ammonium chloride and copper in a solution of cupric chloride and hydrochloric acid. It is claimed for this cell that its electro-motive force is three volts, and that, because of its small internal resistance, it furnishes a current of great quantity. A single large cell, it is said, will run a sewing-machine. Warren claims that it gives a strong, constant current for a long time, and is certainly the most powerful cell known.

Theory of Electrolysis.—Ostwald and the investigators identified with the new school of physical chemistry, have industriously worked upon this subject. The theory of free ions in a solution has been elaborated. By this theory it is assumed that when a salt, such as potassium chloride, is dissolved in a large amount of water, part of the salt molecules are dissociated into free potassium and chlorine atoms

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* *Berichte der Deutsch. Chem. Gesellsch.*, 1894, 2060. *Elektrochemische Zeitschrift*, November, 1894, 144.

† *Chemical News*, **70**, 179.

(ions), and that the current has a directive tendency only on these free ions. Salts which do not thus dissociate give solutions which do not conduct electricity; therefore, all electrolytes are composed of the salts which do dissociate. Further, all electrolysis of aqueous solutions is held to be primary; secondary reactions are regarded as an unnecessary complication of the explanation; the water is always primarily decomposed. Thus, a solution of potassium sulphate is supposed to contain, as free ions, hydrogen and potassium atoms and hydroxyl (OH) and sulphuryl (SO_4) groups. At the negative electrode, hydrogen is separated, and the hydroxyl groups left behind form potassium hydrate with the potassium ions in the solution; on the other electrode, hydroxyl separates, while the hydrogen atoms left behind form sulphuric acid with the sulphuryl ions in the solution.

The above explanation, I beg to observe, is a literal translation of Dr. Le Blanc's own words, and shows us how completely these theorists are begging the question. Your lecturer coincides entirely with the committee of the British Association for the Advancement of Science, that, while many remarkable facts have been recorded, and ingenious experiments made, by the German school, their explanations and theories are insufficient, misleading, and not warranted by the facts. The electrolytic dissociation theory is fundamentally opposed to the doctrine of the conservation of energy, and the attempts of the upholders of the theory to answer this objection satisfactorily, have been altogether futile; indeed, some of their so-called explanations are unworthy of serious attention.

O. Wiedeburg* has recently proven, by very careful experiments, that when the electromotive force at the electrodes is less than the voltage calculated as necessary for decomposition, a very small current passes through the solution, which increases slowly as the voltage increases, and rises very suddenly when the calculated voltage is reached. But the curve showing the quantity of current passing is not vertical at any point, although very steep in the neighbor-

Zeitschrift für Physikalische Chemie*, **14, 174.

hood of the calculated decomposing point. This would show that in the solution some molecules of the salt are bound together with a force less than the average for all the molecules, while others are bound together more strongly. It is only a confirmation of the Clausian theory of molecular motion, and in no sense proves the electrolytic dissociation hypothesis.

The reports of the Electrolysis Committee of the British Association for the Advancement of Science will be found to contain much healthy criticism of these new electrolytic theories.

Electricity Directly from Carbon.—E. E. Brooks* discusses what has been done in this direction. He dismisses thermo-couples with a very few words, as having too low an efficiency ever to be economical on a large scale. The only promising forms are cells using carbon as the negative plate. Nitre is unsuitable as an exciting liquid, because it acts too violently and too much is consumed for economy. The greatest stumbling-block, however, is the material for the positive plate. Platinum is too costly and other metals oxidise too easily. Brown found that by inserting a carbon rod in a Hessian crucible placed in a fire, and another carbon rod in the fire outside the crucible, a difference of potential of 0·2 volts was noticed between the two carbons. On putting nitre into the crucible, the voltage rose to 0·4, the crucible acting as a porous cell. Under similar circumstances, with melted potassium bi-sulphate in the crucible, voltage as high as 1·57 was obtained, and a current strong enough to run a bell. If a few drops of concentrated sulphuric acid were added from time to time, the current could be kept up as long as desired. Brooks concludes that in this case potassium pyrosulphate is the electrolyte.

Ostwald records this experiment: Two vessels containing water are connected by an inverted **U**-tube. In one is placed a platinum electrode, and in the other a zinc electrode, and these are connected by a wire running through a galvanometer. On adding some sulphuric acid to the

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**Elektrochemische Zeitschrift*, 1894, 124.

water surrounding the zinc, brisk chemical action begins, but there is no current in the wire. On the other hand, if the acid be added to the water surrounding the platinum, gas is liberally evolved at the platinum electrode and a strong current is set up in the wire. From this experiment, Ostwald argues that in order to get the full effect of the chemical action converted into electricity, in Jablochkoff's cell (iron and carbon in fused nitre), the oxidising material should be around the iron only, and not in contact with the carbon.

In the future carbon cell, the oxidising material will not be around the carbon, but around the non-oxidising electrode. A cell properly constructed on these principles could burn carbon like an ordinary stove, but what is wanted before we can construct it is a suitable electrolyte, which will act merely as a medium or conveyor of the oxygen, and which will not be consumed. The solution of this problem does not appear impossible.

Borchers* attacks the question from another direction. He argues thus: "It is practically impossible to oxidise carbon satisfactorily in a cell and obtain its energy of oxidation as electricity. The gasification of the coal to carbonic oxide and the subsequent oxidation of this combustible gas in the cold, is the first rational step toward obtaining the electric current." Borchers, therefore, directs his investigations toward a cell in which carbonic oxide is dissolved in a menstruum, and in that condition is oxidised. A solution of cuprous chloride dissolves oxygen, carbonic oxide and hydrocarbon gases. A cell is therefore constructed containing this solution, dipping into which are two copper tubes serving as + poles, and through which carbonic oxide is forced into the solution. Between these is an inverted carbon bell, into which is pumped air, and which serves as the — pole. An electromotive force as high as 0·4 volts is obtained, whereas the oxidation of carbonic oxide should give 1·47 volts. A very feeble current, however, is obtained from a large cell. The correct theory of the chemical

* Report of the first yearly meeting of the German Electro-Chemical Society, October 6, 1894.

actions occurring is not beyond doubt, and the cell is at present very far from being successful in an economic sense.

This gas element has attracted wide attention. Already, L. S. Powell* has suggested an improvement. The carbon electrode is heated red-hot in the air for a short time, giving it a mossy coating, which absorbs oxygen more readily, and makes its action as a porous cell much stronger.

Ozone.—Dr. Fröhlich† reviews the production and utilization of ozone. Siemens and Halske produce it cheaply in large quantity by passing through air the silent discharge of a very high potential alternating current. Two metal tubes are taken, one placed inside the other, insulated from each other by strips of mica, and air is passed between them while the discharge passes from one tube to the other. Or, two thin glass tubes are placed within a third. Inside the inner one is water; between it and the next is the air space, and between the second and third again is water. The two water poles are made the terminals of the current. The ozone thus made is used for disinfection, bleaching wax, oils and sugars, restoring the taste to alcoholic liquors, purifying tobacco and coffee, and for making nitric acid. It is stated that a method has been discovered, and which will soon be published, whereby nitric acid can be made directly from moist air in the ozone tube.

Purification of Drinking Water.—G. Oppermann‡ affirms that "since all natural water contains small quantities of different salts, these can be resolved into their constituents by the electric current, and, under certain conditions, form ozone and hydrogen peroxide, which purify the water by destroying the organic impurities and lower organisms. It is now established that, under proper conditions, water can be completely sterilized by the electric current. The organic impurities can be so completely removed that treatment in the chemical way will show no trace of organic

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* *Electrical Review*, December 7, 1894.

† German Electro-Chemical Society, first meeting, October, 1894.

‡ *Elektrochemische Zeitschrift*, September, 1894. *The Aluminum World*, March, 1895.

matter, and bacteriological tests by gelatine cultures will show no trace of micro-organisms." Oppermann first passes the current through with platinised electrodes. The ozone and hydrogen peroxide left in the water give it an unpleasant taste, to remove which the water is again electrolysed with aluminium electrodes. Precipitated hydrous alumina is formed, which completely clears the water, the glue-like material enveloping the finest suspended particles, entangling and carrying them down with it. In this operation, a current of low voltage and large quantity is used. The precipitate is filtered out, calcined and sold as alumina.

Dr. Lugo simplifies the matter by electrolysing only with aluminium electrodes. This causes a greater consumption of aluminium, but not enough to interfere with the practicability of the process, and the work is done in one operation. The apparatus consists of a trough in which are placed alternately zinc and aluminium electrodes, the latter being the anodes. Water flows continuously through the trough, underneath each aluminium plate and over each zinc plate, passing out at the other end. It is then filtered to remove the alumina. The apparatus can be constructed on any desired scale, and it is reported that plans have been drawn for a plant to purify Passaic River water for the supply of Jersey City, to the extent of 30,000,000 gallons daily.

Purification of Salt-spring Brine.—The usual impurities are the bicarbonates of iron, calcium and magnesium, calcium chloride and sulphate and magnesium sulphate. Collins* passes through it a current of 2·5 volts, which does not affect the common salt, but renders the impurities insoluble. Calcium bicarbonate, for instance, splits up into calcium hydrate (precipitated) and carbonic acid gas, while the latter precipitates more of the bicarbonate as carbonate; the reactions are

$$CaH_2(CO_3)_2 = Ca(OH)_2 + 2CO_2$$
$$CaH_2(CO_3)_2 + CO_2 = CaCO_3 + H_2O + 2CO_2$$

Disinfection of Sewage.—Hermite's process of electrolysing sea-water with the formation of magnesium hypochlorite,

* *Wagner's Jahresbericht*, 1892, 326.

and running this into the sewage, has been subjected to a thorough test at Worthing, England. The medical officer of the local Health Board says, in his report, that there is no instantaneous decomposition of fecal matter, and no complete sterilization of the sewage, and recommends, as an improvement, the passing of the electric current directly through the sewage itself, 2·5 to 3 volts being sufficient to kill all ordinary bacilli.

At Brewsters, New York, the Hermite process has been adopted, however, with great satisfaction.* A current of 700 ampères and five volts is sent through sea-water as it flows slowly between four carbon cathodes (each one foot square), and three platinised copper anodes. The rate of flow is so regulated that the solution is electrolysed to the proper degree, and then is caused to overflow directly into the sewer. The disinfection is practically complete. Comparative tests show that the solution equals in effective strength a one per cent. solution of chloride of lime, which latter would cost 1·4 cents per gallon, while the electrolysed sea-water costs only 0·01 cent.

The process is thus proved to be satisfactory for treating ordinary dilute sewage, but the English tests show that it does not completely sterilize concentrated sewage.

Bleaching.†—Hermite's process consists in decomposing a solution of magnesium chloride, the resulting hypochlorite being allowed to act, either directly on the substance to be bleached, and which is placed in the electrolyser, or by being drawn off, and the bleaching done in a separate tank. The process is in general use abroad, and, to a limited extent, also in the United States. Animal fibres cannot be subjected to this mode of bleaching; it is most usually applied to cotton, linen, hemp, jute and paper pulp. In treating wood pulp, it is subjected to the action of a hot solution of common salt, under pressure, while the electric current is simultaneously passed through. This is effected in a strong digester, patented by Kellner. Electrolytic bleaching costs about one-half as much as the old method with chloride of lime. The

* *Journal American Chemical Society*, January, 1894.

† *Journal of the Franklin Institute*, **139**, 177.

electric current which lights the works at night can be run during the day through the electrolysers.

Dr. Goppelsroeder* reviews the applications of the electric current made by him during the last twenty years, to the production, changing and destroying of coloring matters. He shows how some organic colors are bleached by the current, others changed, and others produced from non-coloring material. By using electrodes of any desired design, acting on fabric saturated with dye, different colored designs are obtained. Or, if the fabric be saturated with a suitable electrolyte, patterns can be bleached upon it in the same way.

Tanning.—Groth† utilizes electricity in tanning by fastening the raw hides on a barrel, which is caused to revolve on a vertical axle, thus forming a cylinder, whose outer surface is pressed upon by a number of long, vertical rollers carrying the current, which is taken away by plates attached to the rollers. The rolling and squeezing force the tannin into the leather, while the electricity facilitates the absorption of the tanning material. During 1894, a plant using this process was started at Orbe, Switzerland, having a weekly output of 300 finished skins.

Purification of Sugar Syrup.—If an impure sugar syrup be subjected to electrolysis, the organic coloring matters are destroyed by oxidation, and many of the inorganic salts present may be removed by using suitable electrodes. Schollmeyer, Behm and Danmeyer‡ heat the syrup to 70° or 75° C., in vessels holding 1·5 cubic meters, and pass a current of 50 to 60 ampères at a tension of 4 volts to each vessel, using electrodes of zinc or aluminium, having a total surface of 12 to 14 square meters. The negative pole soon becomes covered with a gummy coating, which is almost pure albumen, and increases the electrical resistance, to avoid which the current is reversed every two or three minutes. The current is applied only eight to ten minutes, at the end of which time the syrup is run out into a vat and treated

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* *Elektrochemische Zeitschrift*, April, 1894, 3.

† *Elektrochemische Zeitschrift*, October, 1894, 134.

‡ German Patent, No. 76,853 (1894).

in the usual way with milk of lime. The advantages of the electrical treatment are that less milk of lime is needed, and that the use of bone charcoal is done away with. The zinc or aluminium anodes are attacked, forming alkaline salts, which precipitate the impurities of the sugar, while the gummy aluminium hydrate brings down all suspended impurities. Daix* states that one electric horse-power will suffice to refine daily the syrup from 100 tons of beet root, and that the process is in successful use in several of the German refineries.

Bacteriological Experiments.—Smirnow and Klemperer† have made some remarkable experiments concerning the action of electricity on virulent bacteria cultures. It has been proven that when active bacilli of consumption and cholera are subjected to electrical action, the electrolysed liquid gives immunity against fatal quantities of the same bacteria. It has not been proven that it will act as an antidote after the fatal poison has entered the system. Smirnow electrolysed albumin cultures of diphtheria poison, and found at once that, although all the bacilli therein are not killed, yet the liquid thus produced gives immunity to the system against the virulent poison. Experiments with dogs and rabbits have been conclusive, and the medical profession is hastening to apply the serum thus produced in actual practice. The possibility of extending this principle to the treatment of all germ diseases is one of the great questions of modern medical science.

Manufacture of Chloroform.—The electrical method is so cheap and expeditious that it is rapidly displacing all others. An enameled-iron retort is used, having a double bottom by which it is steam-heated. Two lead plates form the electrodes. A twenty per cent. solution of common salt is placed in the retort, brought to the boiling point; the current is caused to flow, and *acetone* is then passed continuously through the electrolysed solution. The free chlorine generated by the electrolysis of the salt acts on the acetone, forming chloroform, which distils off and is collected in a

* *Elektrotechniker*, 1894, 201.

† *Berliner Klinische Wochenschrift*, 1894, 683–742.

suitably attached condenser. Chloroform thus prepared contains no foreign chlorine compounds, and the return per 100 parts of acetone is 190 parts of chloroform out of a possible yield of 206 parts.

Aniline Colors.—The use of the electrical current to produce oxidations and reductions in the manipulation of organic substances, particularly in producing dyes, has been carried so far that it is impossible to attempt even to enumerate them here. In general, the electrolyser is divided into two parts by a porous partition, and, if oxidation be the objective point, the liquid is placed in the anode compartment; or, if reduction, then in the cathode cell.

Cadmium Yellow.—This valuable pigment is easily made by electrolysing a solution of common salt with cadmium electrodes, at the same time leading a current of sulphuretted hydrogen into the solution. Cadmium sulphide is continuously precipitated as quickly as cadmium chloride goes into solution, the pigment being of different shades, according to the conditions of the electrolysis.

Antimony Vermilion.—Chemically, this pigment is antimony sulphide, and may be prepared electrolytically in a manner in all respects similar to that employed in making the cadmium compound, except that antimony electrodes are used.

*Vermilion.**—The following process for preparing mercury sulphide has been described. A wooden tank, one meter high and two meters in diameter, is provided with a shelf near the bottom, on which are placed saucers containing mercury, connected with the positive pole of a dynamo. The negative pole is a *steeled* copper plate lying on the bottom. The liquor placed in the tank contains eight per cent. each of ammonium and sodium nitrates. A perforated coiled tube conveys sulphuretted hydrogen into the tank, and an agitator keeps the whole in motion. From time to time the precipitated vermilion is filtered out.

Scheele's Green.—An eight per cent. solution of sodium sulphate is electrolysed with copper electrodes. The bath

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* *La Lumière Électrique*, 1894, **52**, 376.

is heated by a steam coil, and a little sack containing white arsenious oxide is suspended in the liquid. The current forms copper sulphate and caustic soda. The latter dissolves the arsenic to sodium arsenite, which at once precipitates the copper sulphate as copper arsenite, regenerating sodium sulphate. The process is made continuous by renewing the arsenic and the copper plates, and straining out the precipitated pigment.

Mitis Green.—If the arsenious oxide be replaced by arsenic pentoxide, copper arsenate is precipitated. For this purpose a solution of the oxide is allowed slowly to trickle into the bath around the negative electrode. One electric horse-power produces about one-fifth of a kilo of pigment per hour.

Japanese Red.—This pigment is a lead oxide colored by eosin. It is made electrolytically by electrolysing a ten per cent. solution of sodium acetate with lead plates, an eosin solution being run in continuously during the operation. The precipitated lead oxide takes up the coloring matter as it is forming, and the product is separated by decantation. Rhodamin may be used instead of eosin, and zinc electrodes in place of those of lead.

*Prussian Blue.**—Goebel precipitates a solution of potassium ferrocyanide by means of a ferrous salt, such as copperas; suspends the precipitate in water and electrolyses it. The solution is acidified with five per cent. of an acid and put into the anode compartment of the electrolyser. If the action be prolonged the blue color becomes faint, and the product finally passes into a dark Berlin green.

White Lead.—Stevens† electrolyses a fifteen per cent. solution of nitric acid with lead electrodes, passing in continuously a current of carbonic acid gas. The lead carbonate is precipitated continuously. Ferranti, of London,‡ uses a solution of ammonium acetate and encloses the anodes in porous cells. The electrolysis yields a solution of lead acetate at the anode and caustic ammonia at the cathode.

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* *Engineering and Mining Journal*, January 19, 1895.

† French Patent, No. 216,265 (1892).

‡ English Patent, No. 23,572 (December 21, 1892).

These solutions are run out into separate tanks, and the ammonia is carbonated by running carbonic acid gas into it. The solution of ammonium carbonate is then mixed with that of lead acetate, precipitating white lead, and leaving ammonium acetate in solution to be used over again. This precipitation is performed with the solutions hot. The electrolyser consists of lead plates locked together in a frame, as in a filter-press, the frames being insulated from each other by porous diaphragms of stout Willesdenized paper.

This process, or one similar to it, is already in operation on an experimental scale at the works of one of the largest lead-paint makers in Philadelphia.

Caustic Alkali, Soda and Bleaching Powder.—The practical electrolysis of a strong solution of common salt, producing caustic soda and chlorine gas—the former being used for making carbonate of soda, and the latter, bleaching powder—is of very recent development. On passing the electric current through strong brine the salt is decomposed, caustic soda forms around the cathode and chlorine is set free at the anode. The substances decomposed and the heat absorbed are as follows:

	Calories.
1 molecule of salt in solution (Na, Cl, H_2O)	96,510
1 molecule of water (H_2,O)	69,000
Sum	165,510

The substance formed and heat developed are:

1 molecule of caustic soda in solution (Na, O, H, H_2O)	111,810
Deficit of heat	53,700

$$\text{Voltage required } \frac{53{,}700}{23{,}000} = 2{\cdot}33 \text{ volts.}$$

The practical difficulties encountered in this operation are to find an anode which will not disintegrate rapidly under the combined attack of nascent chlorine and oxygen, and to construct a porous diaphragm which will keep the caustic soda around the cathode from re-combining with the chlorine around the anode.

Greenwood saturates carbon anodes with tar and bakes them at a high temperature. Castner embeds the carbons in powdered carbon and heats them white hot with an electric current, changing them into graphite, which is more resisting. Höpfner claims that both anodes and cathodes can be replaced by ferro-silicon, cast into any desired shape.

Riekmann and Le Seur use a porous partition made of parchment paper soaked in blood and coagulated, the albumin forming the body of the diaphragm. Le Seur uses the expedient of a double diaphragm, into the centre of which the fresh brine is run a little faster than it filters through. The level of liquor in the diaphragm is thus kept higher than in the cell, and as the solution flows both ways into the anode and cathode compartments, a mixing of the liquors in these compartments is thereby prevented. Hargreaves uses a screen of fine copper wire on which asbestos fibre has been deposited. This is said to be the best diaphragm yet used, lasting well and having very low resistance. Hermite has proposed a horizontal diaphragm of mercury, supported on gauze of asbestos or other non-conducting material. Castner uses a movable mercury diaphragm, which will be described in detail.

Kellner avoids the re-combination of caustic soda and chlorine by introducing carbonic acid gas into the cathode liquor and precipitating the soda as bicarbonate. Parker and Robinson propose, since the caustic is largely used in making soap, that fatty acids be introduced into the cathode cell, when the soap produced by the caustic acting on them, floats, and may be skimmed off.

H. Y. Castner, of New York, has patented the following ingenious apparatus:* A shallow vessel is divided into three compartments by two partitions reaching from the top nearly to the bottom. The outer cells are closed by tight lids. Mercury is placed in the bottom, deep enough to reach the partitions and isolate the three compartments. In the outer cells a strong brine solution is kept circulating, and in this are placed carbon anodes, close to the surface of the mer-

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**Engineering and Mining Journal*, September 22, 1894.

cury. Pure water circulates in the middle cell, into which dips an iron cathode. On passing the electric current, the mercury in the outer cells acts as a cathode, and absorbs metallic sodium, while chlorine gas is set free at the carbon anodes and passes into a gas main in communication with the cover. The sodium diffuses into the mercury in the centre cell, the diffusion being assisted by a slight rocking motion given to the whole vessel by a suitable mechanism. In this cell the mercury acts as anode and the iron plate as cathode. The water is decomposed, hydrogen gas is set free at the cathode, while the oxygen liberated at the anode (the mercury) oxidises the sodium in it to Na_2O, which combines with water to form caustic soda. The mercury rarely contains at any time over 0·2 per cent. of sodium. The fittings to each vessel are pipes to the outer cells to circulate fresh brine, a gas main to take away chlorine, and pipes to the inner cell to supply water and take away the caustic solution, which only needs evaporation to be in marketable shape. The plant now in operation at Oldbury, near Birmingham, England, consists of 30 decomposing vessels, a dynamo giving 550 ampères at 120 volts (4 volts to a cell), run by a 110 horse-power engine. The daily output is 1,200 pounds of pure chlorine gas and 1,000 pounds of 99½ per cent. caustic soda. The plant was put in operation in July last, and probably marks the beginning of an immense industry.

Electrolytic soda plants are springing up all over Europe, wherever cheap raw materials (salt, limestone, coal) are available, and particularly where water-power can be had. Already the combined output is nearly 100,000 tons yearly, and Lunge, the Mentor of the soda industry, has given it as his opinion that it is only a question of a few years when the historic *Le Blanc process* and the ingenious *ammonia process* will be entirely eclipsed.

Potassium Chlorate.—By electrolysing a hot solution of potassium chloride, and allowing a free mixture of the caustic potash, chlorine and oxygen produced, potassium chlorate results, the reaction being

$$KOH + Cl + O_2 = KClO_3 + HCl$$

F. Hurter recommends that the solution be electrolysed in a metallic vessel which itself forms the cathode, the anode being formed of thin sheets of platinum. Haussermann and Nachold* hold it the best practice to use a porous cell enclosing the anode, around which circulates a solution of caustic potash, while potassium chloride solution is used outside. The chlorine and oxygen set free at the anode convert the caustic into chlorate, while the chloride solution is gradually converted into caustic. Strong solutions, a temperature of 80° C., and platinum anodes give the best results.

About 2,000 tons of potassium chlorate are used yearly for making safety matches. The *Sociètè d'Electrochimie* at Vallorbes, in the Jura Mountains, Switzerland, operates an electrolytic plant of 2,000 horse-power, and produces yearly 600 tons. The *Superphosphat Aktien Gesellschaft* has erected a 6,500 horse-power plant at Månsboe, in Dalecarlia, Sweden, and at the present time it is probable that all the potassium chlorate marketed is produced by the electrolytic method.

Chromic and Similar Acids.—Placet and Bonnet, of Paris,† produce chromic acid by electrolysing alkaline chromate or bichromate in solution, using carbon electrodes. The cathode is placed in a porous cup filled with pure water, the anode in the chromate solution. Caustic alkali forms around the cathode, and is replaced from time to time by pure water. Chromic acid forms in the outer vessel, and may be crystallized out of the solution. The caustic alkali solution may be utilized to act on chromium minerals to produce the chromate. This principle may evidently be adapted to the treatment of other acids combined with alkaline bases, or, in general, for extracting pure acids from binary compounds.

Phosphorus.—Readman and Parker's‡ electric process is used by the Electric Construction Corporation, at Wednesfield, England. A mixture of calcium acid phosphate and carbon is heated to whiteness in an electric furnace, between

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* *Journal of the Society of Chemical Industry*, September 29, 1894.

† English Patent, No. 22,819 (December 12, 1892).

‡ *Industries*, 1892, 163.

carbon electrodes, and the phosphorus distilling off is caught in a condenser. In the plant now working, an alternating current of 400 kilowatts is used. The intense heat makes the reduction much more complete than in ordinary retorts, the slag remaining containing only a small amount of phosphorus as silico-phosphide of iron, the lime having formed calcium silicate, aluminate and carbide. Albright and Wilson are said to have secured possession of the patents, and will work the process.

Carborundum.—This is the name of a recent product of the electric furnace, a silicon carbide, having the composition CSi. Mr. E. G. Acheson* first made it by heating fine carbon and clay between carbon poles in an electric furnace. Thinking that it was a compound of alumina and carbon, he named it accordingly, in allusion to its presumed resemblance to a combination of carbon and corundum. It is a green, crystalline compound, and so extremely hard that it has found wide practical application as an abrasive material. Made up into wheels it is found to have better wearing qualities than emery, and the fine dust can be used for polishing precious stones and even the diamond. The Carborundum Company, of Monongahela City, Pa., produced, in 1893, 15,000 pounds of this material, which sold at $4 per pound. During 1894, a German works was started at Iserlohn.

The method of manufacture is briefly as follows. A mixture is made in the proportions—

	Parts.
Sand	182
Coke	146
Salt	72

This will produce 100 parts of carborundum.

Two hundred pounds of the mixture are placed in a fire-brick-lined cavity, 6 feet long, 18 inches wide and 12 inches deep. Four carbon electrodes at each end supply the current, and a core of carbon dust starts the arc from one end to the other. The current from a 100 horse-power dynamo is sent through for eight hours, three charges being run per

* *Journal of the Franklin Institute*, **136,** 194.

day. The silicon carbide found between the electrodes is treated seven days with dilute sulphuric acid to remove iron, and is then ready for sorting and working into wheels, etc. The company enlarged its works in 1894, and is doing a flourishing business, the product having gained the reputation of being the best abrasive known.

Calcium Carbide.—This is another recent product of the electric furnace. T. M. Willson,* of Spray, N. C., in the course of experiments to produce alloys of calcium and aluminium, succeeded in forming a black, brittle, fusible substance, which chemical analysis showed to be calcium carbide (CaC_2). From a mixture of

	Pounds.
Burnt lime	2,000
Fine coal dust	1,200

and with the use of 180 electric horse-power for twelve hours, Mr. Willson claims to be able to produce 2,000 pounds of calcium carbide, at a cost approximating $20. This substance promises to be of great industrial value from the curious reaction it gives with water:

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2.$$

In other words, it is converted into calcium hydrate, giving off acetylene gas in the proportion of 100 parts of gas to 247 of calcium carbide, which would mean, approximately, 10,000 cubic feet of gas per ton of carbide. This gas has the highest illuminating power of any known hydrocarbon, and, when mixed with half its volume of air, can be burned without smoking, giving a flame five or six times as brilliant as ordinary illuminating gas. It has been claimed that this gas, equal in illuminating power to coal gas of 25 candle-power per five-foot burner, can be made at a cost of 30 cents per 1,000 cubic feet.† Other and even more important uses for this gas may be found in the field of technical chemistry. For example: by passing electric sparks through a mixture of acetylene and nitrogen, hydrocyanic

* *Engineering and Mining Journal*, December 15, 1894; *this Journal* **139.**, 321.

† Mr. Willson's present claims are much more radical even than this.—Ed *J. F. I.* See this *Journal*, **139,** 321 *et sig.*

acid is formed, from which cyanides can be made. By heating in a sealed tube, it passes into benzene. By an indirect process it can be made to yield alcohol. The difficulties which the projectors are now seeking to overcome are: the danger of explosion of the gas mixed with air, and the decomposition of the carbide by the action of the atmospheric moisture.

Cleaning Metallic Surfaces.—The operation of pickling has been improved by the use of electrolysis. The articles are immersed in dilute sulphuric acid opposite to a negative pole of carbon or wire-gauze, electro-plated with silver and preferably covered with platinum black. On connecting electrically the articles with these poles, by a wire outside the bath, gas is disengaged at the silvered surfaces, while the articles are rapidly and uniformly corroded. If a little nitric or chromic acid be added to the bath as a depolariser, no offensive odors are given off. Another method is to use as a bath, a salt of the metal to be pickled, and an external electric current. The articles to be pickled being used as anodes, they are rapidly corroded, the metal being deposited on suitable cathodes, while the bath remains constant. This method has the great advantage of dispensing with the use of fresh acid, and will doubtless come into extensive use.

THE METALS.

Aluminium.—No very recent improvements have been made in the electrical processes for extracting this new metal. It is now made exclusively by the electrolysis of alumina dissolved in a bath of the fused fluorides of aluminium and sodium, the dissolved alumina being decomposed while the solvent salts are unaffected by the current. The principal works are those at the Rhine Falls, in Switzerland, using 4,000 horse-power, and making three tons daily by Hèroult's process; and the Pittsburgh Reduction Company, making one ton daily by Hall's process. The latter company will presently start a new and much larger plant at Niagara Falls, beginning with a daily output of two tons, which within a year may be increased to four tons. The total output of aluminium in the world, in 1894, was 1,020 metric

tons; the present selling price is thirty-five cents per pound in Europe and fifty cents in the United States. The Swiss works intend extending to 15,000 horse-power within the next five years, when the European price will probably fall to twenty-five cents per pound. The wonderful development of the electro-metallurgy of aluminium is one of the most striking achievements of modern electro-chemical science.

In the utilization of this metal, Mr. J. D. Darling, of Philadelphia, has gained celebrity by electro-plating 100,000 square feet of ornamental iron work on the tower of the new Public Buildings of that city. The question as to whether aluminium could be electro-plated on another metal at all was a doubtful one until Mr Darling began work on this *tour de force.* The chemical composition of the bath used is kept as a trade secret. The columns, etc., to be plated are first coated heavily with copper, in the ordinary way, and then coated over with aluminium one-sixteenth of an inch thick. This last operation takes seventy-two hours, the current used averaging ten ampères per square foot of anode surface, and seventeen ampères at the depositing surface, an electro-motive force of eight to ten volts being used to each bath. Specimens of the work which I have seen are very well done, and reflect great credit on the skill of this Philadelphia electro-metallurgist.

Antimony and Arsenic.—Electrolytic processes for reducing these metals from their ores have been devised, but I cannot say whether they are in practical operation. Siemens and Halske* treat the natural sulphides of these metals with solutions of alkaline sulphide, in which they are soluble, forming alkaline double sulphides. The solution is then electrolysed, separating out the arsenic or antimony and leaving an alkaline sulph-hydrate in solution. The reactions would be

$$\text{(Solution) } Sb_2S_3 + 6NaHS = Sb_2S_3 3Na_2S + 3H_2S.$$

$$\text{(Decomposition) } Sb_2S_3 3Na_2S + 3H_2O = Sb_2 + 6NaHS + 3O.$$

Diaphragms separate the vat into anode and cathode cells, the positive poles being of carbon or platinum.

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* German Patent, No. 67,973.

Chromium.—Pure, metallic chromium is now obtainable in large quantities. It is made by the electrolytic process of Placet and Bonnet.* To a dilute solution of a chromium salt are added the sulphates or chlorides of the alkalies or alkaline-earths; also, certain organic substances, such as gum arabic or dextrin. The solution is one-fifth saturated with the chromium salt and four-fifths with the other substances. The solution is warmed; a cathode much smaller than the anode is used to give great current density at the depositing surface without requiring excessive power, and a current at thirty to forty volts is used for decomposition. To make chromium alloys, the salt of the alloying metal is added to the solution in about equal quantity to the chromium salt. With a low voltage, only the alloying metal (as iron) separates; with higher voltages increasing amounts of chromium are deposited with the other metal, so that any desired proportions can be obtained. Or, the alloying metal may be first deposited alone by using a low voltage, then the desired quantity of chromium by a higher voltage, and the whole plate melted down to form the alloy.

Manganese, Tungsten, Chromium.—Moissan† has found the oxides of all these metals easily reducible in the electric furnace. A current of 300 ampères at 60 volts, passed for six minutes through a mixture of manganese oxide and carbon, gave 100 to 120 grams of manganese, containing from 6 to 14 per cent. of carbon, according to the excess of carbon present. The same current, passed for ten minutes through a mixture of chromium oxide and carbon, gave 100 to 110 grams of chromium containing from 8·6 to 11·9 per cent. of carbon. By mixing this chromium carbide with fresh chromium oxide and heating it again in the furnace, the carbon was eliminated and pure chromium was obtained. Tungstic acid in the same manner gives tungstic carbide, with 17 to 19 per cent. of carbon, which can also be reduced to pure tungsten by heating with more tungstic oxide.

Copper.—The electrolytic refining of copper is now carried on commercially on an immense scale. There are two

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* *The Mineral Industry*, 1893, 560.

† *Comptes rendus*, **116**, 349, 1225.

single plants in the United States, at Baltimore, Md., and Butte, Montana, which have a daily capacity of fifty tons each. In 1894, over 50,000 tons of copper were refined in the United States, and the time is probably not far distant when the whole copper production will be electrolytically refined. The cost of refining at the new Anaconda plant, at Butte, Montana, under the direction of Mr. Thofehrn, is said to be only 0·6 cents per pound. An innovation in the practice of these works is the removal of ferrous sulphate from the solution by warming it and blowing air through, when the iron precipitates as basic sulphate. It is stated that Lake Superior copper is not of as good quality as formerly, because of poorer ores and closer working, and that the Calumet and Hecla Company contemplates changing its smelting plant at Buffalo into an electrolytic plant located at Niagara Falls, where power can be rented at $7 to $10 per horse-power per year. The copper thus refined will command a higher price, and, at the same time, the silver contained in it can be extracted.

Gold.—Münster* claims that he has found in the sea water of Christiania Fjord, twenty milligrams of silver and six milligrams of gold to every 100 cubic meters of water. He proposes to extract these by immersing galvanised iron electrodes in the channel, and passing through them an electric current of feeble tension.

In the cyanide process of treating gold ores, the gold is dissolved in a solution of potassium cyanide. To extract it from this solution, an electrolytic process has been found advantageous. The electrodes must have a large surface; lead is used for the cathodes and iron for anodes; carbon anodes disintegrate too quickly. To precipitate the metal from 100 tons of cyanide solution carrying five dwts. of gold per ton in twenty-four hours, requires 10,000 square feet of cathode surface, and a current of 600 ampères at four volts tension. The iron plates form Prussian blue, but they last a long time. The anodes are placed vertically, and are covered with canvas to keep the Prussian blue out of the

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Engineering and Mining Journal*, **53, 570.

liquid. The lead sheets stand between, with 1·5 inch space between the electrodes. The electrolysing boxes are covered and kept locked, being opened once a month, when the lead plates are lifted out and melted down. They carry two to twelve per cent. of gold, and are cupelled. The expenses are three shillings per ton of liquor treated, and on a large scale it can be reduced to 2·5 shillings; whereas, the ordinary method of precipitating by zinc costs four shillings.*

Parting Gold and Silver.—The Moebius† electrolytic process is used by the Pennsylvania Lead Company, near Pittsburgh, and by the St. Louis Smelting Company. The alloy of gold and silver is cast into anodes, and used in a ten per cent. solution of nitric acid. A current of 1·4 volts per cell is used, and a current density of twenty-six ampères per square foot. The plant at Pittsburgh consists of forty-two cells, run by a current of 180 ampères by sixty volts, there being seven square feet of anode surface in each cell. The output is 20,000 ounces of silver per day. The anodes contain 987 parts silver, 6·3 parts gold, 6·7 parts copper. The deposited silver contains a little copper. The slimes are melted down with silica and borax to an alloy averaging 650 parts of silver, and 300 parts of gold, the remainder being lead and copper. This rich alloy is melted with more pure silver and parted with nitric acid. It is said that this process is cheaper than the ordinary parting process, but one would hardly judge so from the description given.

Lithium.—Guntz‡ mixes anhydrous lithium chloride with an equal weight of potassium chloride, the mixture melting at 450° C., and electrolyses it with carbon anodes 8 millimeters in diameter, and iron cathodes 3 to 4 millimeters in diameter, enclosed in a glass tube, 20 millimeters inside diameter. By keeping the temperature low and using a current of 10 volts and 20 ampères, the lithium is separated and collects in the glass tube. It contains 1 to 2 per cent. of potassium, but is pure enough for most purposes for which it may be used.

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* *Elektrochemische Zeitschrift*, March, 1895.

† *Journal of the American Chemical Society*, January, 1894.

‡ *Comptes Rendus*, 1893, 732.

Magnesium.—This metal is now made only by electrolysis, the sodium method having been entirely displaced. The principal works are those of the Aluminium und Magnesium Fabrik, at Hemelingen, near Bremen. The process consists in the electrolysis of the fused double chloride of potassium and magnesium, reducing gases being introduced under the cover of the vessel to prevent the magnesium from firing. Recently, an alloy, called *Magnesium-Zinc*, has been introduced into commerce as a substitute for pure magnesium. It is an alloy of about 62 per cent. magnesium, 26 per cent. zinc, and 12 per cent. of iron. It is very brittle, can easily be reduced to powder, and is said to answer quite as well as pure magnesium in pyrotechny and photography, while it costs much less. The method of manufacture is to electrolyse the above-named fused salt in a crucible with molten zinc at the bottom for a cathode. In this way an alloy of magnesium with 30 per cent. of zinc is obtained. Some ferrous chloride is then stirred into the bath, which is at once reduced by the alloy, and the iron thus introduced.

Sodium.—Metallic sodium is now made only by electrolysis, and principally by Castner's process.* His works at Oldbury, England, use 1,000 horse-power, and have an output of from five to six tons weekly. A similar plant has recently been erected near Frankfort, Germany. The sodium produced is used either to make sodium peroxide for bleaching purposes, or in the manufacture of organic salts and dyes. The making of antipyrine by Dr. Knorr's patented process involves the use of sodium.

The process consists in the electrolysis of fused caustic soda, kept at a constant temperature of 313° C., in specially constructed cells, each cell taking 1,000 ampères of current and an electromotive force of only 4 to 4·5 volts. The efficiency is about 80 per cent. By keeping the temperature not more than 30° above the melting point of the soda, the electrical resistance is low, the operation proceeds uniformly and the sodium runs off from the top of the bath in a melted state. This last point is of especial advantage, as the distil-

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* *Scientific American Supplement*, July 7, 1894, 15,435.

lation and condensation of the sodium, with all their attendant losses and dangers, are entirely avoided.

J. D. Darling and H. C. Forrest, of Philadelphia, propose* to electrolyse sodium nitrate in a similar manner at a gentle heat, obtaining the sodium melted, and, at the same time, passing the vapors produced at the anodes through water in Wolff bottles, and producing nitric acid. I have not yet learned whether this process is being practiced commercially.

Zinc.—Cassel and Kjellin, of Stockholm†, propose the following process of extracting zinc from its sulphide ores. The ore is roasted as far as possible to soluble zinc sulphate, which is leached out. The electrolysing vessel has a porous partition; around an iron anode is placed a solution of sulphate of iron, while the zinc sulphate solution surrounds the cathode. On passing the current, zinc is deposited from the latter solution, while its equivalent quantity of acid is separated at the iron anode and dissolves it to sulphate. The electromotive force of decomposition, under these circumstances, is the difference between that required to decompose zinc sulphate and that of the iron sulphate, or about one-third of a volt, thus allowing the separation of zinc without decomposing the water of the solution. The process is very pretty in theory, but the porous partitions will be likely to give trouble in practical working, and the question of the cost of the iron used and the market for the copperas produced form large factors in deciding the economy of the process.

Heinzerling proposes to roast zinc ores completely to oxide, and dissolve this out by a concentrated solution of magnesium chloride. This solution is then electrolysed, the zinc separated out, and the magnesium chloride solution used over again. Solution of the zinc oxide is effected hot, under two or three atmospheres pressure. A current of 200 ampères per square meter is used for electrolysis, while the solution is kept as cold as possible.

Galvanising sheet iron by electricity has again been tried, this time at the works of Watson, Laidlaw & Co., Glas-

* English Patent, No. 5,808 (March 20, 1894).

† German Patent, No. 67,303 (1893).

gow, Scotland. The depositing bath contains zinc oxide dissolved in caustic potash, kept warm, and the sheets are kept in motion. The metal is deposited for five to twenty minutes, at the rate of 34 to 134 grams per square meter per minute.

Your lecturer has conducted an extensive series of experiments in refining impure zinc by electrolysis. By using a current density of 100 ampères per square meter, at 1·3 volts tension per bath, and keeping the solution agitated by mechanical means, thick deposits of zinc of exceptional purity can thus be obtained. The accumulation of iron in the solution is prevented by blowing air through it continually, which oxidizes and precipitates the iron as basic sulphate, that can be separated by filtration. There is considerable loss in melting down the zinc sheets to ingot shape; but, notwithstanding this, the process could be operated commercially but for the very low price which zinc has reached within the last few years, the margin for profit being less than in refining copper, while the expenses are greater.

ELECTRICITY DIRECTLY FROM COAL.*

By Alfred H. Bucherer.

The endeavors of scientists and inventors to convert directly the potential energy of coal into electrical energy have received a fresh incentive from the interesting experiments of Dr. Borchers. So alluring are the rewards that follow the solution of this problem that men known for their conservative attitude in similar questions have hailed with extravagant expressions of delight the seeming results of the German electro-metallurgist. It is true the latter deserves high credit for testing his ingenious idea; yet from his own account of the facts brought out in his experiments, I feel sure that as yet his endeavors have been fruitless. Such failure, it is only just to note, could not have been

* To be read at the stated meeting of the Electrical Section, March 26, 1895.

foreseen from the standpoint of our present knowledge of electro-chemistry. In the extensive discussion of Dr. Borchers' work, which appeared in various technical and scientific journals, one point has been altogether ignored, and this point is of such essential importance in the problem of the conversion of the potential energy of coal into electric energy that it deserves to be fully elucidated. This point is the relation of chemical to electrical energy. Dr. Borchers erroneously supposed that it would be possible to obtain an amount of electrical energy from the reaction $2CO + O_2 = 2CO_2$ that would be equal to the heat of formation of as much of the quantity of the reacting substances as take part in the transformation. Since v. Helmholtz has shown that such a view does conflict with facts, it is no longer legitimate to assume its correctness, still less to base upon it efficient calculations, as was done by Dr. Borchers and Ostwald (see *Zeitschrift f. Phys. Chem.*, 1894, p. 521).

The maximum amount of work which we can derive from a chemical reaction is a definite quantity, and is independent of the kind of energy into which it is transformed. Suppose we have an unpolarizable cell and make the external resistance extremely large as compared with the internal resistance; then, if the quantity m of electricity has passed through the circuit, a proportional amount of chemical action has occurred, and the heat developed in the external circuit is equal to the electrical energy obtained. On examination we will find now that although the internal resistance was vanishingly small compared with the external resistance, yet heat has been evolved or absorbed in the interior of the cell, and it follows from the law of the conservation of energy that the heat of reaction Q is equal to the electrical energy E, minus the heat q absorbed in the cell.

$$E - q = Q$$

(1) $$E = Q + q$$

q can have a positive value or a negative value, according to whether heat was absorbed or evolved in the cell. If we consider one electro-chemical equivalent involved in the

transformation and measure Q and q in electrical units, then $E = Q + q$ where E measures the E.M.F. in volts. V. Helmholtz investigated the relation which q has to E by applying the second law of thermodynamics. The following reasoning is similar: We know that the mechanical energy of a perfect engine working between the temperature limits $T + d\,T$ and T is

$$d\,W = q\,\frac{d\,T}{T}$$

(2) $$q = T\,\frac{d\,W}{d\,T}$$

Now, since the second law of thermodynamics holds for the transformation of heat-energy into any other form of energy, it must be true for the transformations occurring in a galvanic cell. Now, as mentioned above, the E.M.F. of a cell measures the energy, if we consider the amount of transformation effected by one electro-chemical equivalent, *i. e.*, the work done by the passage of one coulomb. We can, therefore, substitute $d\,E$ for $d\,W$ and we have by substituting $d\,E$ in (2)

(3) $$q = T\,\frac{d\,E}{d\,T}$$

and, therefore,

(4) $$E = Q + T\,\frac{d\,E}{d\,T}$$

$$\frac{d\,E}{d\,T}$$

is the temperature coefficient, and it follows that if the E.M.F. of a cell increases with temperature

$$T\,\frac{d\,E}{d\,T}$$

is positive, and the E.M.F. is larger than the value calculated from the heat of transformation, and heat is absorbed in the cell; whereas, if the E.M.F. decreases with temperature, the E.M.F. is smaller than the value Q expressed in electrical units. Heat is evolved in the interior of the cell. Now, in some primary cells the temperature coeffi-

cient is so small that it can be practically neglected; in others, it is so great that the E.M.F. as calculated from the heat of formation will give a decidedly wrong value. With a reaction that is so different from those utilized in ordinary cells, and concerning which we know so little as the one utilized by Dr. Borchers, it is not legitimate to form any conclusions as to the E.M.F. obtainable.

The question now presents itself, what is then the maximum E.M.F. we can expect to gain from the combination of carbon monoxide with oxygen? Is there any reversible transformation, no matter into what kind of energy, about which we do know something? There *is* such an ideal process, and I will show the reasoning by which we can arrive at the desired value. The reasoning is based on the principle of the dynamical equilibrium of chemical systems, which principle is nothing else than a disguised form of the second law of thermodynamics. When carbon monoxide combines with oxygen, not all of it is thus oxidized, and at a definite temperature and pressure the composition of the resultant mixture of gases, consisting of CO_2, CO and O_2, is definite. Deville found experimentally that at a temperature of 3,000° Celsius forty per cent. of the carbonic acid is dissociated at atmospheric pressure. I have calculated from this fact that at a temperature of 0° Celsius and atmospheric pressure, the fraction of dissociated CO_2 is

$$\frac{1 \cdot 58}{10^{34 \cdot 86}}$$

If we conduct the process of combination of CO and O in such a manner that the maximum amount is being obtained, and take care that the temperature does not change, then this work depends on the initial and final condition of the gases. Now, let us suppose 2 gram molecules of carbon monoxide, *i. e.*, 56 grams at atmospheric pressure, react on 1 gram molecule, *i. e.*, 32 grams of oxygen, also at atmospheric pressure, in a reversible manner, and that the carbonic acid formed is likewise brought to atmospheric pressure. Then, evidently, since, as we have seen the dissociation of the carbonic acid is extremely small, the partial

pressure of the carbon monoxide in the product of the reaction must also be very small, and the carbon monoxide, while performing work, has been brought from the atmospheric pressure to an exceedingly small pressure. Now, if the partial pressure of the CO be p_1 then the work done is

$$W = 2\,RT\,log._e \frac{1}{p_1},$$

where R is the gas constant referring to 1 gram molecule of gas and is equal to 1·98 calories. The oxygen is similarly brought from the atmospheric pressure to a partial pressure, which is one-half of the partial pressure of the carbonic oxide; for the gases being present in the ratios in which they react on each other, two volumes of CO are present to one molecule of oxygen, and the pressure of the carbonic oxide is twice that of the oxygen. Hence, the work performed by the oxygen is

$$RT\,log._e \frac{2}{p_1}.$$

Since the carbonic acid in the reaction mixture is practically under atmospheric pressure, no work appreciably is done upon it, and the total energy obtained by the reversible combination of the two molecules of CO with 1 gram molecule of oxygen is

$$W = 2\,RT\,log._e \frac{1}{p_1} + RT\,log._e \frac{2}{p_1}$$

(5) $$W = RT\,log._e \frac{2}{p_1^3}.$$

Since now the fraction of the CO_2 that is dissociated at 0° Celsius is

$$\frac{1·58}{10^{34·86}}$$

it follows that the partial pressure p of the CO is

$$\frac{1·58}{10^{34·86}}$$

atmospheres. Substituting this value in equation (5) we have

$$W = RT\,log._e \frac{10^{104·58}}{2}.$$

This energy refers to the chemical combination of 2 gram molecules, and is expressed in calories. To obtain the energy for the combination of one electro-chemical equivalent, expressed in electrical units, we divide by 4×23039, and we have

$$E = \frac{1{\cdot}98 \times 273}{4 \times 23039} \, log._e \frac{10^{104{\cdot}58}}{2} \text{ volts.}$$

$$E = 1{\cdot}41 \text{ volts.}$$

This is the value for 0° Celsius. The heat of formation of carbonic acid is 68000, and the E.M.F. calculated from this is 1·476. Therefore, by the equation of v. Helmholtz,

$$1{\cdot}41 = 1{\cdot}476 + 273 \frac{d\,E}{d\,T}$$

$$\frac{d\,E}{d\,T} = - \frac{0{\cdot}066}{273}.$$

The E.M.F. therefore decreases by

$$\frac{0{\cdot}066}{273}$$

volts, with every increase of temperature by 1°. At the standard temperature, 18° Celsius, the E.M.F. is, therefore,

$$1{\cdot}476 - 291 \frac{0{\cdot}066}{273}$$

$$1{\cdot}476 - 0{\cdot}07 = 1{\cdot}406.$$

We thus see that the E.M.F. is somewhat smaller than assumed by Dr. Borchers. The greatest E.M.F. obtained by Dr. Borchers was 0·5 volts. The conclusion which he now draws from this result is that he has already succeeded in obtaining about thirty per cent. of the energy of the coal, whereas, the steam engine converted much less. This is another non-admissible conclusion. For, in an unpolarizable, *i. e.*, reversible, cell, the maximum E.M.F. is a definite value, and if another value is experimentally observed which very appreciably differs from it, then, barring secondary actions, the reaction which is expected to furnish the electric energy does *not* occur. To say that secondary actions depress the theoretical E.M.F. is not logical in this case, for,

evidently, this secondary E.M.F. would have to be about twice as great as the observed E.M.F., and, therefore, could not be called secondary.

The action that took place in Dr. Borchers' apparatus is most probably one that can be found among those which were investigated and published by Mr. Mond (see London *Electrician*, January 11th, and *Digest Electrical World*, New York, February 2d). It would lead too far to discuss in detail the work of Mond, and to single out the particular action to which the E.M.F. of the apparatus of Dr. Borchers was due.

For reasons which were well stated by the latter, it is more expedient and apparently easier to utilize the combination of carbon monoxide with oxygen for the generation of electric energy instead of that of carbon with oxygen. The work done by Dr. Borchers, though not crowned with success as yet, is, nevertheless, of high value on account of its instructiveness. It indicates in its general features the path that has to be followed for accomplishing a most important industrial task, the fulfillment of which we hope this century will yet witness.

DYNAMO AND MOTOR DESIGN.*

By Gano S. Dunn.

The methods of rating electrical machinery are imperfect, and are less definite than in almost any other class. This is because the factors which limit the load of motors and dynamos are several, and their relations are not generally understood.

A machine has a sparking limit to its load, as well as a heating limit, neither of which limits must be exceeded. What the rating should be will, therefore, be dependent upon the character of the duty. We usually designate a dynamo, or motor, as of a capacity of so many kilowatts or

* Abstract of lecture delivered before the Electrical Section of the Franklin Institute, October 23, 1894.

horse-power respectively. Let us take a motor which, on all-day work, could not deliver more than ten horse-power without overheating; and let us assume that its sparking limit would not be reached until it was loaded to thirty horse-power, which load it could carry for periods of three minutes out of every ten throughout the day.

Now, is this a ten or a thirty horse-power motor? It depends upon the work. It is a thirty horse-power elevator or railway motor. It is a ten horse-power motor for running a printing shop by shafting.

These facts control the design of the machine, and it is my purpose to show how they affect the various proportions.

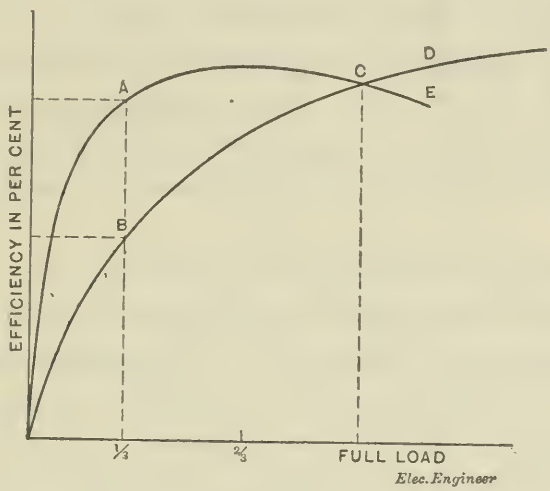

FIG. 1.

In *Fig. 1* are shown the efficiency curves of the two types of machine. These curves differ because of the different distribution of the losses in the machine. Curve *A* represents the efficiency of the continuous running motor, and *B* represents that of the motor whose load is intermittent and excessive. The motor *A* has small fixed losses, such as hysteresis, bearing and brush friction, field current, and comparatively large variable losses, *i. e.*, those which increase with the load, such as the loss due to armature resistance and to commutation.

With motor *B* the reverse is true. The losses in both motors are equal at *C*, but at no other point of the load.

Motor *A* is characterized by a high light load efficiency,

while motor *B* is not. On the other hand, motor *B* never runs at light load, while motor *A* almost always does, as has been found by actual statistics. Readings taken on over 200 motors on commercial circuits showed that these did not average one-third of the rated capacity stamped on their name-plates. The high light load efficiency in motor *A* is of the highest importance, even though it allows the motor to spark if much overloaded; while the ability to stand intermittent, excessive overload, is of the highest importance in motor *B*, even if it is the cause of a low efficiency at light loads, at which, it must be remembered, the motor almost never runs.

Fixed losses are kept low by having a comparatively small amount of iron in armature, which reduces the hysteresis, and winding with comparatively many turns. The small amount of armature iron requires a correspondingly small field circuit to energize it, and this, in turn, a comparatively small amount of copper and current to create the magnetism.

The shaft and bearings may be small.

The type of field selected will have a large influence on one of the losses—field current. When possible, consequent poles should be avoided, and particularly in small machines. The same magnetism can be obtained in salient poles with forty-one per cent. less current and copper. In a comparatively large machine, when the field current is only about one per cent. of the total input, reducing this forty-one per cent. does not affect the efficiency of machine very much; but in a small machine, when field current is, say, ten per cent. of input, reducing by the above amount makes a large difference. The figures of one per cent. and ten per cent. above assumed are the proportions at full load. At one-fourth load they would become four per cent. and forty per cent. respectively, and at this point the advantage of salient poles would be more than ever felt.

The early Edison practice, in which the field magnets were made of many limbs in multiple, was a step in exactly the wrong direction.

Field energy is to be kept low by using coils of circular,

instead of rectangular, section. It takes thirteen per cent. less copper and current to energize magnets of circular, than of square, section. It is advisable, in some cases, particularly in large machines, to use the square or rectangular coil. Rectangular coils are great favorites in England, even in the smaller machines. Elliptical sections are means between the rectangular and circular.

Another feature which keeps the magnetizing field current at a low value, is the selection of a type of field which has a minimum of magnetic leakage. Such fields are those which have their coils in greatest proximity to the armature, and directly facing, or even surrounding it, as in the Eickemeyer machine. In a machine with large leakage, we have to produce many more lines of force than actually go through the armature. This requires larger magnets and larger coils to energize them.

The material of the magnets affects the efficiency and the cost, as follows: Cast iron fields, at two cents per pound, would cost no less than cast steel fields at four cents per pound, since twice as much of the first will have to be used to carry the same magnetism. The steel is the better, however, because, needing to be of only one-half the cross section, less copper is required to surround it, and, therefore, less current. Another advantage of steel over cast iron is that, because of its reduced cross section, it exposes less surface from which leakage may take place.

The armature gives design to every feature of the machine. It may be of heavy core with light winding, or *vice versa*, to meet the conditions of B and A respectively. The use of multipolar machines has brought out many forms of winding. Two circuit windings are those which, although there be more than two poles to the machine, are so applied that there are but two electrical paths between the brushes. This insures that, should all the poles not be of equal strength, there will be no local action between the circuits within the armature. A form of winding coming into more general use is what is known as a double winding. Its purpose is to give a large number of sections to the commutator in places where it is necessary to use but

few turns in the armature, to secure the proper voltage. As machines increase in size, fewer turns are required to produce a given voltage until the number becomes so small that the number of bars between brushes is so small that the potential between the bars exceeds a safe limit, about twenty volts. We overcome this difficulty by the use of a double winding, shown in *Fig. 2*. An armature is wound with two separate and distinct windings, each of the proper number of turns to give the desired voltage, and the corresponding number of commutator bars, too few to be used by themselves. When these two windings are in conjunction, however, and the bars of one winding alternate with those of the other, we secure, as a result, the voltage desired, with double the number of sections to the commutator. Each winding contributes one-half the current, and the

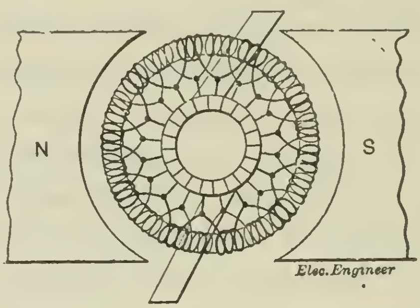

FIG. 2.

brushes, covering at least two bars, are always in contact with both windings.

The sparking of armatures is due usually to the failure of the coil, short-circuited by the brush, to properly reverse its current to make itself ready to take its place in circuit with the rest of the coils after it has left the brush. This reversal of the current may be caused by resistance in the brush, or it may be caused by an E.M.F. established in the coil by causing the moment of short circuit to take place when the coil is under the tip of one of the pole pieces, this being brought about by shifting the brushes. To design a sparkless machine is to take care that the magnetism at the pole tip is not driven away by the reaction of the armature. This reaction is formed by several components, negative ampère turns on the armature and cross-magnetizing ten-

dency, and the knowledge of how to estimate these is what characterizes the designing of to-day from that of the early builders.

As a device (which I have originated) affecting the design of compound-wound dynamos, I would call your attention to the use of a series shunt, whose resistance varies with temperature and the load of the machine. Dynamos which are over-compounded are not worked with full strength of

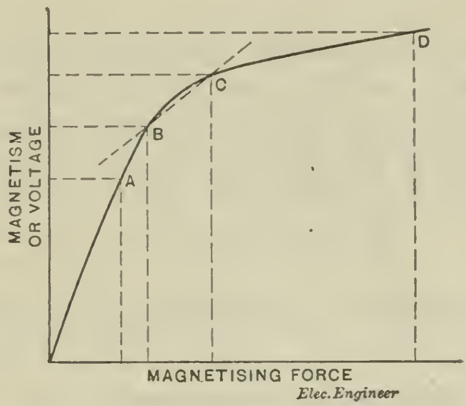

FIG. 3.

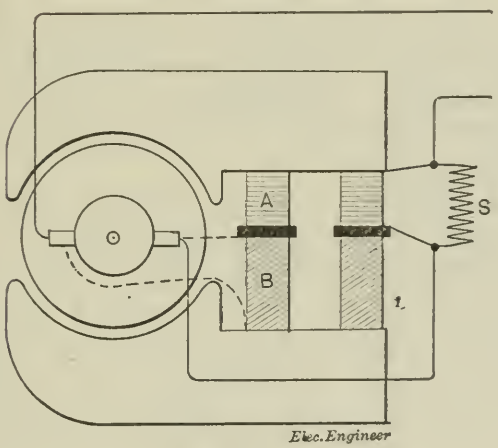

FIG. 4.

magnetism, because it is necessary to have the increase of magnetism, which does the compounding, proportional to the load which needs the compounding, and, at or near full strength, the magnetism of iron is not proportional to the magnetizing force. For this reason the part of the saturation curve from *A* to *B*, *Fig. 3*, is used, instead of the part above *B*. This working at lower saturation reduces the output of the machine.

The part of the curve between B and C may be used by employing the device shown in *Fig. 4*. S is a shunt to the series coils of the dynamo, and it is made of iron or some metal of high temperature coefficient, and may be thermally insulated by a vacuum or by covering with tape. Now, as the load comes on the machine, the current in the series coil A does not increase in proportion to it, but faster, because the shunt S heats up and throws a greater portion of the current into A.

This excess of current in A compensates for the diminishing permeability of the iron at the part of the curve on which we are working, and, as a result, gives an increase of magnetism which is proportional to the load of the machine.

NOTES AND COMMENTS.*

"ARGON," THE NEW GAS DISCOVERED BY LORD RAYLEIGH AND PROFESSOR RAMSAY.

A large audience assembled January 31st, in the theatre of the University of London, to hear Professor Ramsay read the paper on "Argon, a New Constituent of the Atmosphere," communicated to the Royal Society by Lord Rayleigh and himself. The London *Times* gives substantially the following account of the proceedings:

The meeting was noteworthy as being the first devoted to the discussion of a single subject and thrown open to the general public. In a former paper it had been shown that nitrogen obtained from chemical compounds is about one-half per cent. lighter than atmospheric nitrogen. A great many experiments were described which had been made upon nitrogen obtained from various sources. The details of these experiments have no interest for the general public, but the result is to show that nitrogen, from whatever chemical source it may be derived, has a constant density, differing from the density of atmospheric nitrogen by a constant quantity. In whatever way the atmospheric nitrogen may be separated the result is the same, and it was to solve the interesting problem thus presented that Lord Rayleigh and Professor Ramsay embarked upon the laborious experiments which have led to the discovery of a hitherto unrecognised substance. As that substance exists in great quantity in the atmosphere, it is decidedly singular that it has been so long overlooked, and all the more so when we consider that it was undoubtedly isolated by Cavendish, although neither he nor those who have followed him observed the significance of the irreducible gaseous residue from his classical

* From the Secretary's monthly reports.

experiment. When the discrepancy in weights between chemical and atmospheric nitrogen was first encountered, attempts were naturally made to explain it by contamination with known impurities, but finally it became clear that the difference could not be accounted for by the presence of any known impurity.

By considerations drawn from the ratio of specific heats, the authors are led to regard argon as a monatomic gas like mercury, and its atomic weight is, therefore, not 20, but 40. The substance is thus removed from among electro-negative bodies like fluorine, where its density would seem to locate it, to a place among such metallic bodies as potassium and calcium. This gets rid of a serious difficulty, but involves the hardly less formidable one of grouping it with such apparently dissimilar bodies as those just mentioned. In this dilemma the authors are almost disposed to regard argon as a mixture of two unknown elements. However, balancing arguments for and against, they seem, on the whole, to incline to the belief that argon is a single element; but the conclusions which follow are, they admit, of a somewhat startling character. Many attempts have been made to induce it to combine, but they have all as yet proved abortive. In dealing with a substance of so absolutely inert and exceptional a character speculation must necessarily proceed upon rather abstract lines. So far as we have reached at present, argon stands entirely unrelated with any other substance in nature, and every theory of its constitution must accordingly be accepted with extreme caution. As to its physical properties, we have a little more information. Its solubility in water is relatively high, being two and one-half times as great as that of nitrogen. Its spectroscopic examination has been conducted by Mr. Crookes, who contributed a supplementary paper dealing with that portion of the subject. It has two distinct spectra, as has nitrogen itself. But while the nitrogen spectra are of different characters, one being a line and the other a band spectrum, the two spectra of argon are of the same type. According to Professor Olszewski, of Cracow, the critical point of the new gas is —121°; the critical pressure, 50·6 atmospheres; the boiling point, —187°; the melting point, —189·6°, and the density of the liquid, 1·5.

Professor Armstrong, President of the Chemical Society, said that the case for the existence of the new constituent was strong, though it had not been brought forward in such logical order as it might have been. There was a body of evidence that there is in the atmosphere a constituent which has long been overlooked. Nitrogen was regarded as a very inert form of matter, and, apparently, argon was like it, only more so. Conceivably it was diatomic; the atoms might be so firmly connected as to take no notice of anything but each other. The spectroscopic evidence did not justify the conclusion that argon is a mixture of two gases—a point upon which Mr. Crookes evidently wavered.

Professor Rucker, President of the Physical Society, said that beyond all question a new constituent of the atmosphere had been discovered.

Lord Rayleigh observed that, though not unaccustomed to difficult investigations, he had never had a harder task than that which he had carried through with the assistance of Professor Ramsay. He discussed shortly the

evidence which seemed to him and his colleague to lend high probability to the belief that the new substance resembles mercury in being monatomic. He found it difficult to conceive how two atoms could be so intimately combined as to suit a diatomic theory of its constitution, but did not deal with the difficulties involved in supposing it monatomic.

Lord Kelvin joined the Presidents of the Chemical and Physical Societies in congratulating the authors on the brilliant success of their investigations.

THE DISCOVERY OF HELIUM.

In a communication to the London Chemical Society, March 27th, Prof. W. Ramsay says: In seeking a clue to compounds of argon, I was led to repeat experiments of Hillebrand on cleveite,* which, as is known, when boiled with weak sulphuric acid, gives off a gas hitherto supposed to be nitrogen. This gas proved to be almost free from nitrogen; its spectrum in a Pflucker's tube showed all the prominent argon lines, and, in addition, a brilliant line close to, but not coinciding with, the D lines of sodium. There are, moreover, a number of other lines, of which one in the green-blue is especially prominent. Atmospheric argon shows, besides, three lines in the violet which are not to be seen, or, if present, are excessively feeble, in the spectrum of the gas from cleveite. This suggests that atmospheric argon contains, besides argon, some other gas which has as yet not been separated, and which may possibly account for the anomalous position of argon in its numerical relations with other elements. Mr. Crookes has identified the yellow line with that of the solar element to which the name "helium" has been given. Mr. Crookes thus stated that he had been enabled to examine spectroscopically two Pflucker tubes filled with some of the gas obtained from the rare mineral cleveite. The nitrogen had been removed by "sparking." On looking at the spectrum, by far the most prominent line was seen to be a brilliant yellow one apparently occupying the position of the sodium lines. Examination with high powers showed, however, that the line remained rigorously single when the sodium lines would be widely separated. On throwing sodium light into the spectroscope simultaneously with that from the new gas, the spectrum of the latter was seen to consist almost entirely of a bright yellow line, a little to the more refrangible side of the sodium lines, and separated from them by a space a little wider than twice that separating the two sodium components from each other. It appeared as bright and as sharp as D_1 and D_2. Careful measurements gave its wave-length 587·45, the wave-lengths of the sodium lines being D_1 589·51, and D_2 588·91. The spectrum of the gas is, therefore, that of the hypothetical element helium, or D_3, the wave-length of which is given by Angstrom as 587·49, and by Cornu as 587·46.

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*Cleveite is a variety of uraninite, chiefly a uranate of uranyle, lead and the rare earths. It contains about thirteen per cent. of the rare earths, and about 2·5 per cent. of a gas said to be nitrogen.

USEFUL FORMULÆ.

According to *Le Genie Civil*, the Munck process for the *manufacture of artificial whalebone* consists in first treating a raw hide with sulphide of sodium and then removing the hair; following this, the hide is immersed for a period of twenty-four to thirty-six hours in a weak solution of double sulphate of potassium, and is then stretched upon a frame or table, in order that it may not contract upon drying. The desiccation is allowed to proceed slowly in broad daylight, and the hide is then exposed to a temperature of from 50° to 60°; the influence of the light, combined with the action of the double sulphate of potassium absorbed by the skin, renders the gelatin insoluble in water and prevents putrefaction, the moisture, moreover, being completely expelled.

Thus prepared, the skin is submitted to strong pressure, which gives to it almost the hardness and elasticity which characterize the genuine whalebone, with the advantage that before or after the process of desiccation any color desired may be imparted to it by means of a dye-bath. The material can be rendered still further resistent to moisture by simply coating it with rubber, varnish, lac, or other analogous substance.

A simplified process for *silvering glass* is thus described by MM. Auguste and Louis Lumière, in the *Journal de Physique*. Take 100 parts by volume of a ten per cent. solution of nitrate of silver, and add, drop by drop, a quantity of ammonia, just sufficient to dissolve the precipitate formed, avoiding any excess of ammonia. Make up the volume of the solution to ten times the amount by adding distilled water. The reducing solution used is the formaldehyde of commerce. The forty per cent. solution is diluted to a one per cent. solution. The glass to be silvered is polished with chamois leather, and the bath is made up immediately before use, by mixing two parts by volume of the silver solution with one of formaldehyde. The solution must be poured over the surface without stopping. After the lapse of five or ten minutes, at a temperature between 15° and 19° C., all the silver in the solution will be found to have been deposited on the glass in a bright layer, which is then washed in running water. It is then varnished, if the glass side is to be used; or polished, if the free surface is required for reflection. This method does not require the scrupulous care necessary with other methods.

Apropos to formaldehyde, the *Scientific American* reports an interesting application of the substance, which may prove of some value in photography. This is the discovery that formaldehyde has the property of *rendering gelatine insoluble in water*. Gelatine, both in solution and in the dry condition, is said to be rendered insoluble by formic aldehyde, and the jelly after treatment becomes non-fusible. When a very small proportion of formaldehyde is mixed with a warm solution of gelatine, the whole sets on cooling, but can be remelted. If, however, the jelly be spread out and allowed to dry, the gelatine becomes completely insoluble in water, forming a flexible film, which can be used for photographic negative purposes. In both the wet and dry collodion processes, chrome-gelatine is used to insure the adhesion of the collodion to the glass plate, the sensitised collodion

emulsion being poured on to the thin layer of chrome-gelatine previously applied. Instead of chrome-gelatine, formaldehyde-gelatine can be used, but whether with advantage remains to be seen. The applications of formaldehyde-gelatine are patented to A. Zimmerman, London,* and a process for making sensitive films is described in the specification.

When nitrocellulose, dissolved in alcohol and ether, or in soda or potash-soluble glass, is spread over a surface of wood, paper, glass, porcelain, or metal, and the solvent allowed to evaporate, the film remaining is said to have the appearance of *mother-of-pearl.* The proportions recommended are: 1 part of nitrocellulose; 78 parts of alcohol (90 to 100 per cent); 21 parts of ether. With soluble glass as the solvent, 10 parts of this to 90 parts of water are employed.

The nitrocellulose may be pure or crude, or in different stages of nitrification, as gun-cotton, etc. Ethyl or methyl alcohol, and sulphuric or acetic ether, are recommended. The degree of concentration of the nitrocellulose may be varied within certain limits, which variations produce different results. The addition of bisulphide of carbon in the proportion of 25 parts to 100 of the above solution, or the addition of benzine, produces a difference in the brilliancy and arrangement of the colors of the iris developed on the mother-of-pearl-like surface.

The best *cleansing compound for nickel ware* is 50 parts of alcohol and one of sulphuric acid. The article to be cleaned is held in the solution five to fifteen seconds, after which it is washed with water, rinsed with alcohol and wiped dry with a clean rag.

From the *Scientific American*, we learn that Mr. B. Haskell, superintendent of motive-power on the Chicago and West Michigan, and the Detroit, Lansing and Northern Railway, is using *burlap for packing* tender and engine truck boxes. The material is the burlap or sacking that the baled waste is wrapped in. The material is springy and will not mat. Its elasticity keeps it up in contact with the journal and its texture permits the oil to pass through it freely. The material is cut up quite fine preparatory to use. Mr. Haskell writes to *Railway Engineering and Mechanics*, that he finds it to be equally as good as woollen waste, and has the advantage of costing nothing. He furnishes his trainmen with saturated waste instead of oil for oiling cars. To prepare this waste he has built a special tank. It is circular and will hold about six barrels of oil. A coil of steam pipe is run around the inside of the tank, and a shelf of stack netting is secured on one side. About two barrels of oil are turned into the tank and waste enough to absorb that quantity of oil. Steam is then turned on and the oil heated slightly, making it thin enough to be absorbed readily by the waste. It is then allowed to soak for at least twenty-four hours, and, after being again heated, the waste is put on the shelf to drip. The second heating is to make the waste drip more quickly than it otherwise would. A little experience in heating the oil will enable the operator to prepare it so that the oil will drain from the waste without any handling or pressing. It has been found so con-

* British Patent, No. 2036, 1894.

venient that since the plan has been adopted the trainmen are not given oil, but saturated waste instead, and the cost of oiling cars has been greatly reduced thereby.

Cobalt nitrate is found by Dr. Johann Antal, a Hungarian chemist, to be an *antidote in prussic acid and cyanide poisoning.* After having demonstrated its value by experiments on animals, the author administered it to no less than forty persons who had been accidentally poisoned by prussic acid, and in all cases the results are reported to have been satisfactory.

PRODUCTION OF BESSEMER STEEL INGOTS AND RAILS IN 1894.

The Bulletin of the American Iron and Steel Association prints complete statistics of the production of Bessemer steel ingots and of Bessemer steel rails of all weights and sections in the United States in 1894, including a small quantity of standard rails, and a larger quantity of street and electric rails, which were made by manufacturers from purchased blooms. In the statistics of ingots produced are included the production of the few Clapp-Griffiths and Robert-Bessemer plants, and also the production of steel castings by all Bessemer works.

The total production of Bessemer steel ingots in 1894 was 3,579,101 gross tons, against 3,215,686 gross tons in 1893, showing an increase in 1894 of 363 415 tons, or 11·3 per cent.

The total production of all kinds of Bessemer steel rails, including light and heavy, and street and mine rails, in the United States in 1894 was 1,014,034 gross tons, against 1,129,400 gross tons in 1893, a decrease in 1894 of 115,366 gross tons, or 10·2 per cent. The production of Bessemer steel rails in 1894 was composed of 899,120 gross tons rolled by the producers of domestic ingots, and 114,914 tons rolled from purchased blooms.

PIG IRON AT $5.00 PER TON.

An illustration of the claims made for Southern manufacturing locations is seen in a recent statement given out by a company of Northern and Western capitalists who have been investing largely in East Tennessee lands. This statement is to the effect that the La Follette Coal and Iron Company has about 50,000 acres of land, on which are some fifteen or twenty seams of bituminous coal lying horizontally one above the other. This company also owns 7,000 or 8,000 acres of iron ore land, which runs from fifty-four to fifty-nine per cent. metallic iron. The coking coal and the iron ore are said to be within the extremes of half a mile, and between the two is an unlimited quantity of limestone, the three being so situated that they can be delivered at the furnaces by gravity, without the use of steam. The gentleman making these statements predicts that pig iron of a quality sufficient to make basic steel will be produced at this point within a period of eighteen months, at a cost not to exceed $5 00 per ton.

This is the lowest figure yet mentioned as the cost of producing Southern pig iron. Within the past year it has been stated that pig iron was being

made with washed coke at a total cost of $5.99 per ton, in the Birmingham, Ala., district. A journal devoted to Southern manufacturing interests said at that time that the cost in the Birmingham district had been cut down to less than $6.50, a reduction of $3.00 per ton from the lowest figures reached six or seven years previous. A later estimate placed the figures at $6.37. At various times Southern pig iron has been put into this market at figures which, if there was anything in the trade, would put the cost of production even below $5.00 per ton, but such sales have always been under peculiar circumstances. We are inclined to think that even with the great natural advantages claimed by the company mentioned, $5.00 pig iron will hardly be produced in the near future.—*American Manufacturer.*

THE BALTIC AND NORTH SEA CANAL.

During the latter part of June it is expected that the canal connecting the Baltic and North Seas will be opened for commerce.

The line of the canal starts at Kiel, on the Baltic Sea, and crossing the Prussian Province at Holstein, joins the Elbe at Brunsbuttel, below Hamburg. Work was begun on June 3, 1887, and over 8,600 men were employed during the summer months, while in winter the number was reduced to about 4,700. The plant comprised 90 locomotives, 2,473 cars, 66 dredgers, 133 lighters and 55 engines. The estimated cost was M 156,000,000 ($37,440,000), and the thoroughness of preparation and efficiency of execution cannot be better illustrated than by mentioning the fact that the estimate has not been exceeded.

There will be two locks: one at the Baltic end, open all the year round, except during 25 days; and one on the Elbe, open three to four hours during every flood tide, so that it may almost be termed a tidewater canal. Its length is 53½ miles; average depth, 29½ feet; width at bottom, 72 feet; width at water level, 213 feet.

At Brunsbuttel, on the Elbe, there is an outer harbor 1,312 feet long by 328 feet wide; then follows the lock, 492 feet by 82 feet and 32⅘ feet deep, and then an inner harbor 1,640 feet by 656 feet. Two suspension bridges cross the canal nearly 138 feet above water level, so that railway traffic will not be interrupted.

The speed allowed on the canal will be 5·3 miles per hour, making the time of passage about thirteen hours. The toll will be 75 pfennigs, or 18 cents per net register ton (loading capacity). It is expected that about 18,000 ships will make use of the canal annually, representing about 7,500,000 tons. Hitherto about 35,000 ships passed every year through the Skager Rack and the Cattegat, between the Baltic and the North Sea, so that the estimated percentage seems fair. The saving of time will be considerable, since for all ships bound to or from any point south of Hull the distance will be reduced by 238 miles, while Bremen ships will save 322 miles and Hamburg ships 424 miles. But more important than the saving in time is the avoidance of danger, the passage through the Sound between the Scandinavian Peninsula and Jutland being considered one of the most dangerous in

Europe. Statistics show that about 200 vessels founder every year on these coasts.

The strategic value of the canal is, beside, of the greatest value to Germany, because its men-of-war will be able to pass from the North Sea to the Baltic with ease and safety, avoiding the passage through foreign waters, and permitting rapid concentration on the North or the West coast.—*Engineering and Mining Journal.*

OUR TIN-PLATE CAPACITY.

Secretary John Jarrett, of the Tinned Plate Manufacturers' Association, publishes a statement concerning our tin-plate industry. It appears from the statement that when the tin-plate mills under construction and those projected are finished and running, the output of tin-plates in this country will be over half a million boxes above the present annual consumption of tin-plates in the United States. The annual consumption is given at about 6,000,000 boxes, which includes the tin-plates exported by the Standard Oil Company and the various canneries. The capacity of mills built and building is given at 4,980,000 boxes annually. If those projected are built, Mr. Jarrett says that the output would be 6,720,000 boxes. But we annually export about 1,500,000 boxes in the form of cans of all sizes, and if it be assumed that this part of our supply is always to be obtained abroad, then our strictly domestic consumption is reduced, according to Mr. Jarrett, to about 4,500,000 boxes.

By examination of the Treasury statistics we find that the imports of tin-plates during the four fiscal years ended June 30, 1890, amounted to 2,623,006,255 pounds, or an average of 655,751,564 pounds per year, equivalent to 6,557,516 boxes of 100 pounds each. As no tin-plates were made in this country during the years mentioned, the domestic consumption is practically represented by the imports for the period. During the four fiscal years ended June 30, 1894, the imports of tin-plates amounted to 2,541,251,204 pounds, and the domestic production in the three years ended June 30, 1894, as ascertained by the Treasury Department, was 252,689,388 pounds, making the total available supply during the four years 2,793,940,592 pounds, or 27,939 406 boxes. This gives an average annual supply of 698,485,148 pounds, or 6,984,851 boxes during the past four fiscal years. For the past eight years the average annual supply of tin-plates has been 6,771,183 boxes, and this practically represents the average yearly consumption during that period.

It will be observed that Mr. Jarrett's figures of the annual consumption of tin-plates in this country, including the export trade, are too low by from half a million to a million boxes. It should also be seriously taken into account that many of the prospective tin-plate works mentioned by Mr. Jarrett may never be built. Besides, it is almost too much to expect that all the works actually constructed will annually work up to their full capacity. We have no doubt that eventually we will have the capacity to produce more tin-plates than we can consume, but it is too soon, in our opinion, to assume that this result has been reached, or that it is dangerously near.

We concede, however, that if we are always to obtain abroad the tin-plates that we export in various ways, because these tin-plates may be obtained virtually free of duty owing to the drawback provision of the tariff, then our capacity to produce tin-plates is already near the actual home consumption. But why assume that exported tin-plates will continue to be made abroad?—*Bull. Iron and Steel Association.*

BOOK NOTICES.

Electric Transmission of Energy and its Transformation, Subdivision and Distribution. A practical handbook. By Gisbert Kapp. (4th edition, thoroughly revised.) New York: D. Van Nostrand Company. 1894.

Those of our readers who are interested in electrical science will be so familiar with the previous editions of this excellent handbook, that no introduction will be required in making reference to the appearance of a 4th edition.

In this the author has been compelled, by the enormous strides that have taken place in connection with electric power-transmission since the appearance of the previous editions, to modify considerably the scope of the work. The historical portion of the subject has accordingly been entirely omitted, as has likewise the detailed description of a number of transmission plants.

On the other hand, the present edition devotes considerably more space to the theory of continuous current machines, while the theory of alternators and multiphasers has been added. W.

Annuaire pour l'An 1895, publié par le Bureau des Longitudes; avec des notices scientifiques. (Price, fcs. 1.50.) Paris: Gauthier-Villars et fils. 1895.

This publication, issued annually by the "Bureau des Longitudes," contains, in conveniently accessible form, all the information that would naturally be looked for in a nautical almanac, together with a large amount of miscellaneous information respecting the coinage, statistics, geography, mineralogy, chemistry, etc. Among the specially interesting communications contained therein is one by Berthelot, giving a series of thermo-chemical values revised and corrected to date. W.

The Source and Mode of Solar Energy.—By I. W. Heysinger, M.D. Philadelphia: J. B. Lippincott Company. 1895.

The above-named work is an ingenious speculation in which the author seeks to account for the origin and maintenance of the solar energy. Like others who have preceded him in the study of this fascinating problem, notably Meyer and Sir Wm. Siemens, the author finds the explanation in sources exterior to the sun. His views on the subject are interesting and forcibly presented, and the book will repay perusal. W.

A Laboratory Manual of Physics and Applied Electricity.—Arranged and edited by Edward L. Nichols, Professor of Physics in Cornell University. In two volumes. Vol. II. Senior courses and outlines of advanced work. By George S. Moler, Fred'k Bedell, Homer J. Hotchkiss, Chas. P. Matthews, and the Editor. New York: Macmillan & Co. 1894. Price, $3 25.

This is the companion volume to the manual for beginners in physics, which was lately reviewed in these columns, and is intended for the guidance and instruction of advanced students, who are prepared to undertake special work.

The book is divided into four parts, viz.: Experiments with direct current apparatus; experiments with alternating currents; senior courses on heat and photometry; and outlines of advanced work in general physics. The first three parts have been prepared with especial reference to the needs of those who are preparing themselves for the profession of electrical engineer. The method followed in the work is the presentation of experimental studies of the most important problems occurring under each chapter head. W.

Encyclopédie Scientifique des Aide-Mémoire. Paris: Gauthier-Villars et fils. (Price, per vol., fcs. 2.50, unb.; fcs. 3, bound.)

The following additional volumes of this practical and comprehensive encyclopædia of the arts and manufactures have been issued since the publication of the previous reference thereto in this *Journal.*

Dudebout et Croneau. Ingénieurs de la Marine. *Appareils accessoires des chaudières à vapeur.*

Leloutre, Georges. Ingénieur civil. *Le Fonctionnement des Machines à vapeur.*

Hatt. Ingénieur hydrographe de la Marine. *Des Marées.*

Vallier. Chef d'escadron d'Artillerie, Correspondant de l'Institut. *Balistique des nouvelles poudres.*

Jacquet, Louis. Ingénieur des Arts et Manufactures. *La fabrication des eaux-de-vie.*

La Baume Pluvinel, A. de. *La Théorie des procédés photographiques.*

Bourlet, C. Professeur au Lycée Henri IV, Docteur ès Sciences. *Traité des Bicycles et des Bicyclettes, suivi d'une application à la Construction des Vélodromes.*

Sorel, E. Ancien ingénieur des manufactures de l'État. Professeur suppléant au Conservatoire des Arts et Métiers. *La Distillation.*

The foregoing volumes are uniform in appearance, each forming a small octavo, and complete in itself. Each subject is treated by a competent specialist. The convenient form of the separate parts of the series, and the condensed yet thorough treatment which each subject receives, render this work an extremely useful one. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, April 17, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1895.

Mr. JOS. M. WILSON, President, in the chair.

Present, seventy-two members and thirteen visitors.

Additions to membership since last report, nine.

The paper of the evening was read by Mr. E. D. Smith, on the Chicago Drainage Canal.

The speaker gave an account of the general scope of this important work, and of its salient engineering features; also, of the methods employed in its construction, the present state of the work, etc. The paper was profusely illustrated by means of lantern views made from photographs taken on the scene of operations. It was discussed by the author, Prof. Lewis M. Haupt, Messrs. Spencer Fullerton, G. M. Eldridge, Warner Walter, the President, the Secretary and others.

On Mr. Fullerton's motion, the thanks of the meeting were voted to Mr. Smith for his interesting and instructive presentation of the subject.

The Secretary, in his monthly report, gave a description, with the aid of a view upon the screen, of the new steel cantilever bridge about to be built over East River at Blackwell's Island, New York. (A brief account of this structure appears in the annual report of the Secretary, published in the February impression of the *Journal.*) He also gave a brief account of a number of important ship canals, either under construction or projected, in Europe and America.

The Secretary referred also to the fact that the evidence, which Lord Rayleigh and Professor Ramsay had succeeded in accumulating in demonstration of the existence of "argon," the alleged new constituent of the atmosphere, is now believed to be so convincing, that the genuineness of the discovery may beregarded as having been placed beyond doubt. He referred also to the probable identification, by Professor Ramsay, of "helium"—ahypothetical element heretofore believed to exist only in the sun—in a mineral of terrestrial occurrence.

Of new inventions, there were presented and described, an under-surface conduit system for electric trolley railways, devised by Mr. Joshua M. Hammill; and a trolley-car fender, invented by Mr. Frederick Fiechter.

Adjourned.

WM. H. WAHL, *Secretary.*

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CHEMICAL SECTION.

Stated Meeting of March 19, 1895.

DR. W. C. DAY, President in the Chair.

[The President announced the paper for the evening, and introduced the speaker.]

COMPOSITION OF THE AMERICAN SULPHUR PETROLEUMS.*

BY CHARLES F. MABERY,
Professor of Chemistry, Case School of Applied Science.

One of the most interesting exhibits in the Department of Mines in the Columbian Exposition was the extensive collection of crude petroleums, refined products and diagrams illustrating the petroleum industry, shown by the Standard Oil Company. Of the marvelous development of our natural resources during the last thirty years, perhaps a more striking illustration could not be presented than that afforded by the petroleum exhibit.

Since the early discovery of petroleum in this country the manufacture of products obtained from it has been distinctively an American industry. In the history of its development we are struck with the great skill and originality in methods which were devised for sinking wells to great depths, and, when necessary, for removing obstacles to the free outflow of oil by exploding the wells with torpedoes, as well as in the application on a large scale of methods of fractional distillation for the separation, in a single operation, of commercial products from the crude oil. We are also impressed with the inventive genius displayed in the construction of peculiar forms of lamps, burners and heaters for household use; and in the discovery of manifold uses for the various distillates in cleansing, lubrication and medicine, and in the manufacture of soaps, candles, solvents, electric light carbons and numerous other products.

The specimens of crude oils in the Columbian Exposition showed all gradations in color between transparent or nearly colorless oils and those which were very dark and opaque, such as are used in the ordinary processes of refining. So far as it appears from the results of numerous investigations on the composition of crude petroleums from different localities, they are more nearly alike than is indicated by the inequalities in color. The main points of difference depend upon variations in the proportions of the hydrocarbons, which constitute the commercial products, such as the naphthas, gasolines, burning oils and lubricating oils.

The single method available for the examination of crude petroleums depends upon the wide variation in the boiling points of the constituent hydrocarbons, which renders possible a separation sufficiently complete for the preparation of commercial products. By this method the hydrocarbons of lower boiling points have been isolated and identified, and the composition of the more volatile portions of the crude oils has been determined with precision. Unfortunately the less volatile constituents, the hydrocarbons which distill above 250° or 300°, suffer decomposition during distillation, or, as it is termed by the refiners, they undergo "cracking." Even under diminished pressure, although a

larger quantity may be distilled, the temperature soon rises to a point at which there is considerable decomposition of the heavier distillates, and this increases with the temperature, until finally there is left in the still a mass of porous carbon representing a considerable portion of the original oil. On account of this decomposition by distillation, and the lack of any other method for the separation of the less volatile constituents of crude oils, our knowledge of this subject is still incomplete.

The discovery and subsequent development of the Ohio sulphur petroleum mark a notable epoch, even in the midst of the wonderful growth of the petroleum industry in other fields. Even with the advantage of former experience, the novel problems presented for solution in the new fields, at first, baffled the best skill of the driller and the refiner. Fortunately, from the beginning, ample opportunities were afforded for thorough scientific study of the geological formations encountered in sinking wells and the mode of occurrence of the oil, as well as of the technological features of its production. To appreciate the thorough manner in which such knowledge of the Ohio gas and oil fields has been collected and placed on record by Prof. Edward Orton, State Geologist of Ohio, it is only necessary to consult the Eighth Annual Report of the U. S. Geological Survey, and the Reports of the Ohio State Geological Survey for 1888 and 1890. These reports contain a vast amount of valuable information concerning the new gas and oil territory.

In attempting to present the merest outline of the mode of occurrence of the Ohio sulphur petroleums, I shall refer to some of the results obtained by Professor Orton in his exhaustive study of the Trenton limestone formations, with which the oil deposits are associated.

It is now well known that the distribution of petroleums within the United States is restricted to quite limited districts as compared with the total area, and that besides differences in the oils from different localities, of color, transparency and varied proportions of the individual constituents, the oils of certain fields have peculiar characteristics which

depend upon the presence of a considerable proportion of sulphur compounds. It is interesting to note that these sulphur petroleums are found only in districts quite distinct from those of the sulphur-free oils.

Public attention was first attracted to the Ohio sulphur petroleum by the discovery, in November, 1884, at Findlay, in that State, of oil and gas in considerable quantities. In that part of the Northwestern section of Ohio, known as the Black Swamp, the presence of gas and oil in creeks and pools has been known since this section of country was first inhabited; but the last decade has here witnessed a marvelous development of these natural products. The immense deposits of gas are now apparently nearly exhausted, but the copious flow of oil still continues. In the exploitation of oil in Ohio, the prospectors had all the advantage of twenty years' experience in the fields of Pennsylvania. The methods of sinking wells, as well as the manipulation of oil and the modes of treatment in refining, had been highly perfected. Markets were ready to receive the refined oils, and no time was lost in waiting for the discovery of uses for the various products. It is true that an over-stocked market has led to a large consumption of the crude oil for fuel at a quarter of its real value, but this destructive use cannot long continue.

The first oil was obtained from a well drilled at Lima, in May, 1885, and soon afterward, in the same year, oil flowed freely from a well bored at Findlay. The first production from the Hume well, in 1886, was at the rate of 250 barrels per day. In May, 1887, there were, in the Lima field alone, 445 wells producing daily 9,488 barrels; the greatest daily production of any single well was stated to be 5,000 barrels.

The discovery of a productive source of oil in the lower Silurian limestone seems to have been a great surprise to both geologists and oil-men, although the presence of oil in this limestone had previously been maintained by T. Sterry Hunt (*Am. Journ. of Science*, II, **35**, 168). As was expressed by Orton, the enormous flow of gas and oil from the dolomitic Trenton limestone constituted a new chapter in the history of petroleum production, and one of great interest, since the

Trenton beds form the most important single source of petroleum in the United States. Later developments have not only confirmed earlier observations, but have shown also that the sulphur petroleums are to be obtained in quantity, in the central part of the United States and Canada, only from the older limestones.

The Trenton limestone, one of the older formations of the continent, extends from New England to the Rocky Mountains. Occasionally outcropping, it forms excellent building stones; when burnt, valuable lime; and, by decay, fertile soils. Frequently it underlies the entire strata of large areas without appearing at the surface. In northwestern Ohio, where it forms the reservoir of the sulphur petroleums, it is usually from 1,000 to 2,000 feet below the surface, beneath a succession of shales (Utica, Hudson River and Medina) from 400 to 1,000 feet in thickness. Although the limestone seems to be permeated throughout with oil, the uppermost beds, to a depth of from 20 to 30 feet, contain the accumulated stocks, a bittern of peculiar composition occupying the space beneath.

With the history of the development of Trenton limestone oil and gas, as one of the centers of enormous production, the town of Findlay is intimately associated. The dolomitic composition of the limestone, which experience has shown to be an essential condition for gas or oil, is here present. Gas is derived from areas less than 400 feet below the sea-level, with Niagara limestone as the surface rock. The village is divided into two nearly equal portions; the east side, occupied by the Niagara limestone, is gas territory; and the west side, occupied by the Lower Helderberg or water lime, is oil territory.

The essential features of petroleum production are source, reservoir and cover. In the Ohio fields the Trenton limestone, as the reservoir, is never wanting in oil; and the superimposed beds of impervious shales, in depths of from 500 to 1,000 feet, furnish the cover. The necessary porosity is due to the fact that the oil rock is a dolomite of highly crystalline structure. The intercrystalline spaces furnish adequate storage for large deposits of oil. The thickness of

the upper strata of the dolomitic limestone which constitutes the reservoir, is usually from five to ten feet, occasionally from fifty to 100 feet. In the Lima field, thirty feet below the surface of the Trenton limestone is recognized as the limit of the level of value for oil. The conditions, then, for the storage of oil in economic quantities depend upon a dolomitic composition of the limestone (which seems, also, to be the source as well as the reservoir), with an overlaying, impervious shale, as a cover.

Around each productive field there appears to be a sharply drawn "dead line," marking the boundaries between oil or gas and salt water, which is the propelling force of the confined oil or gas; and they occupy different levels, depending upon the height of the reservoirs. At Findlay and in the Lima fields, the highest level of the reservoirs is 300 feet below tide; the salt water level was originally 500 feet below tide at Findlay, and 400 feet below at Lima. In Indiana, the "dead line," or salt water line, in the porous reservoir, is less than 100 feet below tide. This area of 30,000 square miles is a plain over nearly its entire extent, with the Niagara limestone as the surface rock where gas is found, and the Lower Helderberg the surface rock, where oil is abundant. In the absence of outcropping oil rock, these surface indications are important guides for the location of new wells. The location and limits of the salt water line were soon learned, and, with minor exceptions, 500 feet was accepted as the limit below which it is not profitable to drill.

In 1863, Dr. T. Sterry Hunt (*Amer. Jour. of Science*, II, **35**, 170) explained that the petroleum supply of Western Ontario was derived from a broad, low anticlinal; and he maintained that the anticlinal structure is necessary in connection with hydrostatic pressure to the production of a large supply of oil. This theory has been fully confirmed in Ohio, where the flat, low-lying terraces, having a very slight elevation above the surrounding country, afford sufficient storage for immense quantities of oil. For the most part, the Ohio terraces are nearly level, with slopes of less than 1°; in general, the range in elevation throughout 100 square miles does not exceed 100 feet.

In extent, the Lima field is from eight to ten miles in length, and from two to three miles in breadth. The elevation of the surface above the sea level is from 800 to 900 feet; the gas rock is nearly level and about 380 feet below tide.

The Findlay field is also a low, nearly horizontal terrace of Trenton limestone, about 1,250 feet deep and two miles wide in a north and south line, by less than five miles east and west. The plains of Northern Ohio form the cover of the most prolific oil field yet found on the American continent, and second only to the great Russian field in the Caucasus (Orton, Geol. Report), and yet the deposits of oil seem to be singularly restricted in area. Outside of the Ohio and Indiana horizon, drillings 1,000 miles distant have yielded neither gas nor oil, the Trenton limestone failing to be a source beyond this limited district.

The two conditions under which Trenton limestone has yielded oil or gas are porosity and relief. The highly crystalline dolomitic composition supplies porosity, and a slight warping of the strata furnishes a reservoir in which are stored the enormous quantities of oil and gas above the salt water. Dr. Hunt described this brine as derived from the saline deposits evaporated from the ancient seas. In an examination of the brine from Trenton limestone, Lord found that it consisted chiefly of the chlorides of sodium, calcium and magnesium. In numerous examinations made in this laboratory, of salt brine collected in wells drilled for gas, there have been found bromine, iodine and lithium.

Oil is very widely distributed in the Ohio limestone. Hunt estimated the Chicago oil dolomite to be one foot thick and to contain one-tenth of one per cent. of oil. The same quantity in the Ohio rock would furnish, in every square mile of strata 500 feet thick, more than 2,500,000 barrels of oil; in a depth of 1,500 feet, 75,000,000 barrels. As determined by Lord, the amount of oil in the shales is equivalent to one-fifth of one per cent. Calculating this proportion for each square mile, to a depth of 1,000 feet, the total amount would exceed 10,000,000 barrels (Orton). The amount of oil in the Ohio rocks, therefore, is large even beyond computation,

but it has no economic value except when accumulated under pressure in reservoirs.

Throughout the oil and gas regions in Ohio and Indiana, the salt water in the Trenton limestone rises under free flow to about 600 feet above tide. The pressure is attributed to salt water collected in artesian reservoirs in the porous limestone which rises to the surface in Michigan and Illinois. It is there open to the admission of surface waters, which exert a pressure proportionate to the head, and the oil and gas collecting by gravitation in the limestone reservoirs are subjected to a corresponding pressure.

Professor Orton suggests as a probable explanation of the formation of the oil rock, that the original pure limestone, formed from crinoids, was replaced in part by magnesic carbonate derived from sea water, and as the new crystals did not completely occupy the spaces left vacant by the removal of the crystals of calcic carbonate, the infiltration of liquids became possible. The limited series of collected facts and observations is not sufficient to explain the precise character of the metamorphic changes.

In Canada, petroleum seems to be distributed in limited quantities over an extensive area, but not in sufficient accumulations to have economic value. The presence of oil on the waters of creeks and pools first attracted attention at Oil Springs in 1860-61. Dr. Winchell estimated that not less than 5,000,000 barrels of oil flowed off on the waters of Black Creek during the spring and summer of 1861. The sole supply of oil is derived from the territory at Petrolia and at Oil Springs, the former with an area of eight square miles, and the second two square miles in extent. The geological formations are here even less complicated than in the Ohio oil fields, since the oil deposits are much nearer the surface. The same conditions of structure are found, viz.: source, reservoir and cover, that have been established in Ohio. Instead of the Trenton limestone, the prolific source in the neighboring territory, the Corniferous limestone contains the oil deposits, with a corresponding shale above, which serves as an impervious cover. The following section of a well at Oil Springs (H. P. Brummel, Can. Geol. Rep., 1888-

1889) explains the composition of the rock strata at this point.

	Feet.
Surface	60
Upper limestone	35
Shale (upper soapstone)	101
Middle limestone	27
Shale (lower soapstone)	17
Lower limestone	130
	370

The wells are supposed to be sunk sixty feet into the Corniferous limestone.

Section near the Imperial refinery, Petrolia—

	Feet.	
Surface	104	Hamilton
Upper limestone	40	Hamilton
Shale (upper soapstone)	130	Hamilton
Middle limestone	15	Hamilton
Shale (lower soapstone)	43	Hamilton
Hard white limestone	68	Hamilton
Soft limestone	40	Corniferous
Gray limestone	25	Corniferous

The geology of the Canadian oil deposits was first investigated by the late Dr. T. Sterry Hunt, and on his conclusions was based the first and most probable explanation of the origin and storage of limestone oils (*Am. Journ. of Science*, II, **35**, 168). He asserted that these oils owe their formation to the decomposition of animal remains in the midst of a marine calcareous deposit. The cavities of the shells and corals afforded sufficient space for the storage of the oil as it was formed. It is here clearly stated that the limestone is both source and reservoir. Whatever may have been the conditions of formation of petroleum and its deposition in other regions, subsequent developments in the Ohio fields have fully confirmed that portion, at least, of Hunt's hypothesis, which makes the older limestone formations the reservoir of the petroleums in question.

The Canadian oil deposits are much nearer the surface than those in Ohio. As shown above, the depth of wells at Petrolia was formerly less than 400 feet, and at Oil Springs

less than 200 feet. In the township of Enniskillen the depth and flow of several early wells were as follows:

	Barrels Daily.
At a depth of 155 feet	2,000
" " 158 "	3,000
" " 167 "	6,000
" " 188 "	6,000
" " 237 "	7,500

It is therefore evident that the flow of oil from some of the Canadian wells has been very large. In 1889 there were thirteen refineries, nine at Petrolia and four at Oil Springs. The supply of oil came from 3,500 wells, of which 2,500 were at Petrolia. The monthly production at Oil Springs amounted to 20,000 barrels, and the annual consumption, as nearly as could be estimated, was 704,690 barrels. At present the total number of wells is 8,000, of which about 6,000 are in operation at Petrolia. The annual production, as estimated by one of the best-informed oil men at Petrolia, is 800,000 barrels annually, including the monthly output at Oil Springs, which is 17,000 barrels. The average depth of wells at Petrolia is now 465 feet, and at Oil Springs, 380 feet. From the large number of wells, it is evident that the average daily production of individual wells is small. When first drilled, a well may yield a barrel or more daily, but the flow finally falls to one-half or one-third of a barrel. The small daily yield, however, is offset by the long life of the wells. Most of the wells flow steadily during long periods, some as long as thirty years.

A peculiar method of storage has here been adopted, depending upon the impervious quality of the Erie clay. It consists of a tank, in the earth, 30 feet in diameter and from 50 to 60 feet deep, having a wooden lining to a depth of 30 feet. The surface of the tank below the wooden casing is of clay, and the capacity of the tank is from 5,000 to 10,000 barrels. The total capacity of the tanks in both fields is 1,000,000 barrels. Oil is collected from the individual wells in wagon tanks and brought to receiving tanks, from which it is pumped to the central stations near the refineries.

Canadian oil is refined in the ordinary manner. Much gas is evolved, which, as usual, is serviceable in heating the retorts. In the crude still, gasoline and burning oil are run off to 37° Beaumé, and the residue is then transferred to the tar still, from which heavy oils are distilled to 30°·5 Beaumé, and the residue coked. The last distillate is again distilled and the residue coked as before. In refining, much depends upon the skill of the operator. With careful treatment and the use of an alkaline solution of plumbic oxide, a burning oil of excellent quality is prepared. From Petrolia crude two per cent. of naphtha is obtained, and from Oil Springs, seven per cent. The yield of burning oil from both sources is forty-three per cent. The quantity of tar is thirty per cent. of the crude oil, from which the yield of heavy oils is twenty per cent., with a residue of coke equivalent to ten per cent.

The anticlinal system is well marked in the Canadian fields, and is similar to that of the oil-bearing limestone formation in Ohio. The anticlinals are low terraces, and the oil collects on the slopes toward the summit, where it is held under pressure by the salt water. The variations in the oil-bearing strata have been carefully studied by Messrs. M. G. Woodward and F. J. Carman, from whom I obtained valuable information concerning this and other features of oil production in the Canadian fields.

At present the main producing field at Petrolia is five miles in length and two miles in maximum width, on an anticlinal, which takes the direction of W.N.W. by E.S.E. Much prospecting has been carried on outside of the producing fields, and has shown that the Corniferous limestone is reached at Petrolia, at 335 feet. Sixteen miles distant from Petrolia, at Sarnia, in a west-northwesterly direction, it descends to a depth of 503 feet. East of Petrolia the stratum again dips to 390 feet, and again rises, and at this point many attempts, some partially successful, have been made to discover another deposit similar to that at Petrolia. Still farther distant, in a southeasterly direction from Georgian Bay, the Corniferous limestone outcrops; and still farther away, the Trenton limestone appears at the surface.

The latter formation may be reached beneath the Petrolia anticlinal at a depth of 2,000 feet or more, but it is not, as in Ohio, an important reservoir of oil. Independently of the main producing fields in this section, much oil has been taken from "pockets;" indeed, the great producing wells seem to have derived their supply from these sources. Two years ago, while surveying a section just outside the line of productive territory, and partly surrounded in a semicircle by flowing wells, an oil man suggested the possibility that a pocket might be found in this space. Upon sinking a well, oil was found in quantity, and it proved to flow, as predicted, from a pocket which has since yielded a large supply.

The oil territory at Oil Springs is situated on an anticlinal parallel to that which supplies oil at Petrolia, and ten miles distant. As already explained, the oil rock is nearer the surface, and in addition to the great wells which undoubtedly came from pockets, until recent years the daily flow was ten or fifteen barrels. At present it does not much exceed the flow at Petrolia previously mentioned. It has been thought very probable that the anticlinal which contains the Oil Springs deposit encloses other deposits, and, consequently, much prospecting has been done along the direction of this anticlinal, especially in the township of Euphemia, where oil has been found in limited amounts, at a distance of twenty miles from Oil Springs.

In studying the geology of the sulphur petroleums, striking differences are observed in comparing the geological formations in different localities. While it seems very probable that the deposits of oil in the Ohio and Canadian territory have been formed in the limestones by the decomposition of animal remains, in other localities sulphur petroleums are found in rock formations essentially different from the limestone deposits. In the volume of the Geological Survey of Kentucky, published in 1891, Orton gives an account of the geological formations connected with the oil deposits in that region. While similar conditions of source, reservoir and cover are there found with porosity and the anticlinal structure, a black shale constitutes the rock in which the oil is stored, placing the oil in the Devo-

nian formation instead of in the lower Silurian, which is the horizon of the Ohio sulphur oil. It is explained that the essential difference in the rock formations in which oil is stored is only in degree, as is shown by the wide distribution in Ohio, where there is scarcely a geological formation that does not contain oil. The different shales contain it in variable quantities, but the necessary conditions of accumulation (impenetrable cover, etc.) for economic production are wanting.

In reviewing the distinctive properties of the limestone oils, as compared with Pennsylvania oil, Orton states in this report that they are dark in color, heavy, with a high specific gravity, and a rank odor from the sulphur compounds they contain. In these respects it is found that the oils of Canada, Kentucky and Tennessee, the new field in Northwestern Ohio, and the oil of the Utica shale and Hudson River group, in the latter State, are similar. In accounting for the storage in the shales, their natural agency is based upon their impervious quality, which prevented rapid decomposition of vegetable matter, with the aid also of the affinity of the clay for oil.

A marked peculiarity in the geological formation containing deposits of sulphur petroleum is found in California. These deposits have been carefully studied by Professor S. F. Peckham (Geol. Surv. of Cal., Vol. 2, Appendix). The source of the California bitumen is invariably a bluish slate or shale, more or less compact, with a variable mixture of fine quartz sand. There are occasionally outcroppings of bitumen, but the conditions of reservoir and cover, which have been found essential in oil deposits where oil is stored under pressure, here seem to be largely or entirely wanting, with the result that the oil deposits exert a low pressure if any. The oils obtained from these deposits are quite different in their properties from the Pennsylvania oils, and, in fact, from any other American oils that are the source of commercial products. Their specific gravity is very high (0·875–1·653), and very small quantities distill within the limits of burning oil distillates; in fact, without resorting to cracking, probably very small quantities of illuminating

oils can be prepared from this petroleum. The percentage of sulphur is higher than that of the other sulphur petroleums, as well as the percentage of nitrogen, which varies between 0·56 and 1·12. As is pointed out in the description of this petroleum, there is strong evidence in favor of its formation from animal remains. Certain constituents of the crude oil are so unstable that when exposed to the air for some time the oil becomes impregnated with maggots.

A description of the occurrence of petroleum in any particular district can hardly be considered complete without some reference to the enormous deposits of oil at Baku, on the shore of the Caspian Sea. Although the oils from this region contain no considerable quantity of sulphur, in some respects and with reference to certain other constituents, the sulphur oils may be found to resemble the Russian product. As in other oil regions the sections furnishing oil at Baku are quite limited in extent. The great district of Balakhani, with an area of from four to five square miles, is about eight miles north of Baku on the coast; and two or three miles south of Baku on the seashore is another very small district, Bibi-Eibat. Statistical or other reliable information concerning the Russian oil fields is meagre, and the points here presented are taken from the report for 1886 of the United States Consul, J. C. Chambers, at Batoum. According to this report the depth of the wells varies between 175 and 1,030 feet.

The deepest well at Bibi-Eibat, 700 feet deep, produced from 30,000 to 40,000 barrels daily during fifteen days, after which it ceased to flow. Very little information is accessible concerning the geology of the Baku district beyond the fact that the oil is derived from the Tertiary formation.

FORMATION OF PETROLEUM.

The formation of petroleum has received much attention from both the chemical and the geological point of view, and the prevailing theories have been ably presented and discussed by Professor Orton in the reports mentioned above. Until the discovery of great quantities of oil in the Trenton limestone, the geologists, in this country at least,

attributed the formation of petroleum exclusively to the decomposition of vegetation. The early suggestions of Hunt that the formation should be referred to animal remains in the limestones of the primitive rocks, attracted little attention until they received support from recent discoveries. Abroad, the prevailing belief seems to have been that the formation of all petroleums should be referred to the decomposition of animal remains. Credence is still given by some writers to the theory of Mendelejeff that all petroleums have been, and are still, formed by the action of water on iron or iron carbides, highly heated within the earth; but for lack of proof and the serious objections based upon observed facts, urged by geologists, this explanation is not generally accepted. At present the data collected seem to be insufficient to establish any particular method of formation. Even if the theory of animal origin be accepted for the limestone oils, it cannot be asserted that vegetable remains may not have been in part instrumental.

In 1865 Warren and Storer (*Mem. Amer. Acad., N. S.*, **9**, 177) subjected a lime soap prepared from menhaden oil to destructive distillation, and obtained a hydrocarbon, naphtha, from which they separated several series of hydrocarbons identical with those which Warren (*Mem. Amer. Acad., N. S.*, **9**, 156) had previously identified in Pennsylvania petroleum. More recently, Engler (*Ber. der deutsch. chem. Gesellsch.*, **21**, 1816) submitted the American menhaden oil to destructive distillation under high pressure, and, in the product distilled, was able to identify the constituents ordinarily separated from natural petroleum, including naphtha, the burning oil hydrocarbons, and paraffine. Engler therefore concludes that all petroleum has been derived from the decomposition of similar organic remains under the same conditions. Probably no better summary of the present state of the theories concerning the origin of petroleum can be given than that suggested by Orton (*Geological Survey of Ohio*, Vol. VI., p. 82).

(1) "Petroleum is derived from organic matter.

(2) "Petroleum of the Pennsylvania type is derived from

the organic matter of bituminous shales, and is probably of vegetable origin.

(3) "Petroleum of the Canada type is derived from limestone and is probably of animal origin.

(4) "Petroleum has been produced at normal rock temperatures (in American fields), and is not a product of destructive distillation of bituminous shales.

(5) "The stock of petroleum in the rock is already practically complete."

CHEMICAL COMPOSITION OF PETROLEUM.

Although various attempts had previously been made to separate the constituents of petroleum, the first systematic examination was undertaken in 1862 by Pelouze and Cahours (*Compt. Rend.* **54**, 1241; **56**, 505; **57**, 62), who identified the presence of the series of hydrocarbons C_nH_{2n+2}, beginning with butane, boiling at 0°. From their results, Pelouze and Cahours assumed that the heavier oils and paraffine have the same composition as the hydrocarbons of lower boiling points, and, as a generic term for the series, Watt suggested the name paraffine hydrocarbons, by which these constituents of petroleum have since been known in chemical literature. Members of the same series were observed by Schorlemmer (*Journ. Chem. Soc.*, 1862, 419), in a product distilled from cannel coal; and in a distillation of American petroleum, Schorlemmer obtained other members of the series that had been overlooked by Pelouze and Cahours. C. M. Warren (*Mem. Amer. Acad., N. S.*, **9**, 156; *Proc. Amer. Acad.* **27**, 56) undertook a more thorough investigation of Pennsylvania petroleum, conducting the separations in a fractional condenser which he had devised especially for such distillations. In a long course of distillations, Warren separated two series of hydrocarbons, beginning with butane, with an homologous difference in boiling points for CH_2 of 30°, and with a difference in boiling points between the members of one series and the isomeric members of the other, of a little less than 8°. One of the series, C_nH_{2n+2}, identified by Warren, terminates at 127°·8, the other at 150°. The fractions of higher boiling

points were found to contain members of the series C_nH_{2n}. The results of Warren indicated, in the distillates above 150°, the absence of members of the series C_nH_{2n+2}, notwithstanding the assertions of Pelouze and Cahours, that distillates from these portions of petroleum have the composition homologous with marsh gas. In the earlier examinations of American petroleum by Pelouze and Cahours and by Schorlemmer, it is somewhat uncertain to what extent Pennsylvania crude oil was employed, and to what extent Canadian oil, since in allusions to the crude product American petroleum is mentioned, with occasional reference to Pennsylvania or to Canada as the particular source.

The presence of aromatic hydrocarbons in American petroleum was first established in 1856, by Schorlemmer, who identified benzol and toluol in a distillate collected below 150° from Canadian petroleum, by treating this portion of the oil with nitric acid, reducing with tin and hydrochloric acid and distilling with sodic hydrate. The oil distilled had the odor of aniline and gave the rosaniline reaction with bleaching powder. The distillate between 150° and 170° gave a mixture of liquid and solid nitro-products, and the solid portion was recognized as trinitrocumol. Benzol and its homologues have since been found in Pennsylvania petroleum by several chemists. Petrocene was investigated by Sadtler (*Amer. Chem. Journ.*, **1**, 30). From American kerosene, in a portion distilling at 170°–190°, Engler (*Ber. der deutsch. chem. Gesellsch.*, **18**, 2234) separated pseudocumol and mesitylene, by the formation of nitro-compounds, and he estimated that the quantity present in crude Pennsylvania oil is equivalent to 0·2 per cent. Engler also identified these hydrocarbons in German, Galician, Italian and Russian petroleum; in the latter, to the extent of 0.1 per cent. After ascertaining in the petroleum of the Central Caucasus the presence of hexahydro-derivatives of the aromatic series, Beilstein and Kurbatoff (*Ber. der deutsch. chem. Gesellsch.*, **13**, 2028) examined American ligroin for the same hydrocarbons, but succeeded in identifying only hexahydroisoxylol. No at-

tempts were made to ascertain the presence of the higher homologues.

The petroleum from various localities in the Caucasus has been quite thoroughly investigated by Russian chemists, and it has been found to differ in its composition very essentially from Pennsylvania oil. It is held by Mendelejeff, Engler and others, that none of the petroleums, so far as they have been examined, differ essentially with respect to their components; but that the observed variation in the qualities of different oils depends rather upon a variation in proportions. This difference in proportions, however, is so marked, that in certain oils some of the constituents constitute nearly the whole body of the oil, with others present only in minute quantities, in comparison with other oils, in which the former constituents are almost entirely absent, the great body of the oil consisting of substances nearly wanting in the first. The thorough investigations on the composition of the Caucasus petroleum by Markownikoff and Ogloblin (*Ann. Chim. Phys.*, VI, **2**, 372) proved the presence, in oil from Baku, of benzol, toluol, iso-xylol, pseudocumol, mesitylene, iso-durol, durol and higher hydrocarbons with their structure not yet determined, $C_{11}H_{14}$, $C_{11}H_{12}$, $C_{12}H_{14}$, and $C_{13}H_{14}$, with indications of the homologues of styrol and phenylacetylene. The results of Beilstein and Kurbatoff indicate the presence in the petroleum from the Central Caucasus, of members of the series, C_nH_{2n+2}, with benzol and toluol, and that the oil from the coast of the Caspian Sea consists mainly of the homologues of hexahydrobenzol. In the oil from the Balechene plain on the Apscheron peninsula, Markownikoff and Ogloblin found large quantities of the aromatic hydrocarbons; but in oil from the Central Caucasus they found naphtenes to the extent of eighty per cent. of the crude oil, and the aromatic hydrocarbons to the extent of ten per cent. At first, Markownikoff looked upon the naphtenes as isomeric with the hexahydro-compounds; but later Markownikoff and Spady (*Ber.*, **20,** 1850) appeared to accept the identity of octonaphtene and hexahydroisoxylol. Markownikoff and Ogloblin proved also the presence of hexahydromesitylene,

besides other oils with the composition C_9H_{18} and the members intermediate to $C_{15}H_{30}$.

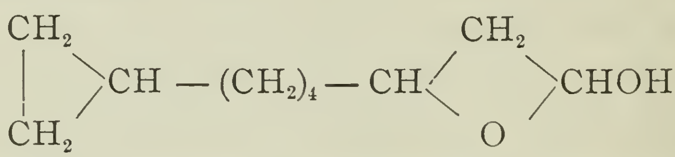
Benzol and its homologues were identified in Hanover petroleum by Bussenius and Einstuck (*Ann. Chem. und Pharm.*, **113**, 167), and by Ulsmann (*Ann. Chem. und Pharm.*, **114**, 279). In petroleum, from Boryslaw, in Galicia, Lachowicz (*Ann. Chem. Pharm.*, **220**, 187) found benzol, toluol, isoxylol and mesitylene; but of the hexahydro series, only hexahydroisoxylol. Pawlewski (*Ber. der deutsch. chem. Gesellsch.*, **18**, 1915) found in Galician petroleum two per cent. of aromatic hydrocarbons, chiefly benzol and *p*-xylol, the latter recognized for the first time in any petroleum. Naphthalene, anthracene, their homologues and other allied hydrocarbons, have been reported from various sources.

Concerning the presence of unsaturated hydrocarbons in crude petroleum, there seems to be a wide difference of opinion. Some investigators have doubted the existence in crude oil of these bodies, and where they have been found in distillates it has been assumed that they have resulted from decomposition by distillation. In the lower fractions of Galician oil, Lachowicz obtained no reaction with bromine, even after long standing. Above 200°, the presence of unsaturated hydrocarbons, indicated by the ready absorption of bromine, was attributed to decomposition. On the other hand, Engler states that petroleum from Elsass (Pechelbronn), Oelheim (Hanover), Tegernsee, Pennsylvania, Galicia and Baku, contains members of the series, C_nH_{2n+2}, and the series C_nH_{2n}, both unsaturated hydrocarbons and naphtenes. Markownikoff and Ogloblin (*Ber.*, **16**, 1873) allude to the presence of unsaturated aromatic hydrocarbons in the oil from Baku.

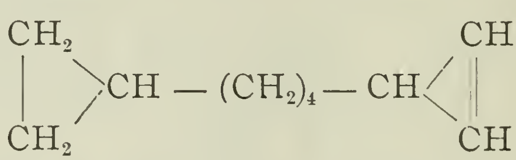
Before the discovery, by Wreden, of the hexahydroaromatic compounds, Warren separated from Pennsylvania petroleum a series of hydrocarbons C_nH_{2n}, which were probably of the same series. It now seems probable that the constituents of Pennsylvania petroleum above 150°, assigned by Pelouze and Cahours to the series C_nH_{2n+2}, really belong to another series.

It has long been known that analyses of crude petroleum

have shown less than 100 per cent. of carbon and hydrogen, and the deficiency has been attributed to the presence of oxygen. The first attempt to separate oxygen compounds from crude petroleum was made in 1874, by Hell and Medinger (*Ber.*, **7**, 1216), who agitated crude petroleum with a solution of sodic hydrate and then added sulphuric acid in excess to the alkaline solution. The oil which separated was distilled and converted into a methyl ether; by saponification of this ether an acid was obtained, to which was assigned the provisional formula $C_{11}H_{20}$. Aschan (*Ber.*, **23**, 867; **24**, 1864; **25**, 3661) obtained a mixture of acids by the addition of sulphuric acid to the sodic hydrate solution used in the refining of Baku oil; one acid, $C_8H_{14}O_2$, was obtained, that distilled at 237–239°; and another, $C_9H_{16}O_2$, that distilled at 251–253°. Aschan called the first acid octonaphtenecarboxylic acid; by distillation with hydriodic acid it was converted into hexahydroxylol. By similar methods Zaloziecki (*Ber.*, **24**, 796, 1808) separated oxygen compounds from petroleum, which were readily oxidized to acids when exposed to the air. For one of these bodies, assuming it to be a lacto-alcohol, Zaloziecki suggested the formula



and to the hydrocarbon obtained by distillation, he gave the formula



Engler asserts that the acids separated by this method are oxidation products of other constituents of the crude oil. Markownikoff and Ogloblin stated that the distillate 75°–85°, from Caucasus oil, contained 0·76 per cent. of oxygen compounds, and the fraction 220°–230°, 5·21 per cent. The oxygen compounds are in part acid, in part neutral, and in part phenol. The acids $C_{10}H_9COOH$ and $C_{11}H_{11}COOH$ were

obtained as colorless oils (*Ber.*, **16**, 1878). Markownikoff and Ogloblin regarded these substances as naphtenecarboxylic acids. Sainte-Claire Deville (*Comptes Rendus*, **66**, 442; **68**, 485; **69**, 1007), showed that the percentage of oxygen in oils from different localities varies between 2·1 per cent. in the Canadian petroleums, and 5·6 per cent. in the oil from Zante.

Most of the petroleums contain nitrogen, usually in minute quantities. Beilby (*Jour. Soc. Chem. Ind.*, **10**, 120) found 0·08 per cent. of nitrogen in the residuum from Pennsylvania oil, and 0·37 per cent. in the coke, which corresponds to 0·008 per cent. of the crude oil; crude Russian oil gave ·05 per cent. of nitrogen. In examining oils from different localities for nitrogen, Peckham (Geol. Survey of Cal., vol. ii, Appendix) found in petroleum from West Virginia, 0·54 per cent.; in Mecca oil, 0·23 per cent.; and in California oil, from 0·56 to 1·1 per cent. In Egyptian oil, Kast and Kunkler (*Chem. Centralbl.*, 1890, 932) found 0·3 per cent. of nitrogen, 1·21 per cent. of sulphur and 0·2 per cent. of oxygen. Certain alkaloid bases were detected in paraffine oils by Weller (*Ber.*, **20**, 2097), and Bandrowski (*Monatshefte für Chem.*, **8**, 224), by agitating Galician oil during several weeks with sulphuric acid, obtained a substance containing nitrogen. This substance solidified at 20°, and it formed a platinum salt containing 19·7 per cent. of platinum. Zaloziecki (*Monatshefte für Chem.*, **13**, 498) neutralized a sulphuric acid extract from the refining of a petroleum distillate with calcic hydrate, and distilled with steam. The oily distillate contained nitrogen, and it formed a platosochloride whose percentage composition corresponded to that of tetrahydrocorridine

$$(C_{10}H_{19}NCl)_2\ PtCl_2,$$

or to the formula

$$(C_{10}H_{21}NCl)_2\ PtCl_2;$$

another insoluble platoso-compound was obtained, to which was assigned either the formula

$$(C_{10}H_{15}NCl)\ PtCl_2, \text{ or } (C_{10}H_{17}NCl)_2\ PtCl_2.$$

Soon after the discovery of the Ohio sulphur petroleum, in a technical examination of crude oil which I was called upon to make, I observed that it contained an unusually large amount of sulphur. An examination of the crude oil was soon undertaken, with particular reference to the sulphur compounds, and there was finally separated an homologous series of sulphides $(C_nH_{2n+1})_2S$, including methyl-, ethyl-, propyl-, butyl-, isobutyl-, pentyl-, ethyl-pentyl-, hexyl-, with higher distillates containing sulphur compounds not yet identified (Mabery and Smith, *Proc. Amer. Acad.*, **24**, 218; *Amer. Chem. Journ.*, **16**, 83). Large quantities of distillates have been collected after long distillation *in vacuo*, which have proved to be mixtures of sulphur compounds, unsaturated hydrocarbons C_nH_{2n}, and apparently saturated hydrocarbons, either of the series C_nH_{2n+2}, or of the series of hexahydro-aromatic compounds C_nH_{2n}.

The sulphur compounds in Canadian oil have received some attention (preliminary examination, Mabery, *Amer. Chem. Journ.*, **16**, 89). Several members of the series $(C_nH_{2n+1})_2S$ have been recognized since that publication, with evidence of sulphides of another series. The separation of the sulphur compounds from the distillates is extremely tedious, even after a long-continued fractional separation of the sulphur oil. The sole method available, so far as we have proceeded, includes precipitation with alcoholic mercuric chloride and decomposition with hydric sulphide in the presence of alcohol. The product is a mixture, the constituents of which must be separated by prolonged fractional distillation.

The peculiar character of the distillates was observed while studying the sulphur compounds, and, as the Ohio petroleum had never been submitted to chemical examination, and the Canadian oil to only partial study, both products invited further attention. On account of the tendency to decomposition manifested by other constituents of the crude oils than the sulphur compounds, it was evident that these bodies could not be separated by the ordinary process of distillation without such serious decomposition as to render the results of little value. When dis-

tilled in contact with the air all distillates, except the most volatile, were highly colored. Attempts were therefore made to avoid decomposition so far as possible by the exclusion of air, and by conducting the distillations under reduced temperatures. In order, furthermore, to be sure that the distillates should represent as nearly as possible the original constituents, we started with crude oils instead of refinery distillates. In certain portions of our work connected with the separation of constituents that are present in minute quantities, requiring large quantities of material, we have used crude distillates as the starting point; but these distillates were not treated with reagents before we received them.

The distillation of considerable quantities of crude oil *in vacuo* involved certain difficulties which we were long in overcoming. Metallic stills could not be used, and glass was unsafe with large quantities of oil. Only earthenware and porcelain remained, and we have found it difficult to procure earthenware that would support a vacuum. Certain English and German stills of limited capacity have been found serviceable, but the stills which are perfectly satisfactory for such work are those manufactured in the Royal Berlin porcelain factory. One of these stills, with a capacity of fifteen liters, has been in use almost continuously during several months, and it has apparently suffered no deterioration.

In maintaining a vacuum for the continuous distillation of petroleums, especially those containing considerable quantities of sulphur compounds, rubber corks cannot be used in making connections, on account of softening action of the oil on the rubber. It is nearly impossible to select common corks sufficiently free from imperfections; but it was found that common corks could be treated with a rubber lute in such a manner as to make them air-tight. This lute is best made by dissolving pure caoutchouc in very light gasoline, which readily evaporates, leaving a thin, strong film of rubber. When this lute is applied to joints of the apparatus, during the formation of a vacuum, the film of rubber is drawn into the joints and pores of the corks,

thus sealing them permanently, and with an occasional application of the lute there is no difficulty in maintaining any desired vacuum.

In prolonged distillation it is important to regulate the tension, so that it shall be constant during the collection of all distillates. For this purpose a special form of regulator was devised, depending upon the introduction of air away from the still, through a glass stopcock, by means of a long lever. By this means it has been found possible to control the vacuum at any desired point with very little attention. The difference in boiling points in vacuum distillation varies between 60°-65° for the lower constituents, and 100°-125° for portions distilling at 300°-350°. Vacuum distillation prevents serious decomposition even of the highest distillates. We have carried the temperature to 375°, and this is as far as distillation is possible with ordinary connections. The residue above this point is a thick oil, apparently undecomposed; cracking is easily observed, since it immediately destroys the vacuum. For further distillation of this residual oil an apparatus must be devised to avoid the use of any connections other than glass or porcelain.

We have undertaken an examination of Ohio and Canadian petroleum with reference to the various series of hydrocarbons, the nitrogen compounds, the oxygen compounds and the sulphur compounds. This paper gives an account of results obtained in an examination of distillates collected below 150 atmospheric pressure.

[*To be concluded.*]

The NICARAGUA CANAL.*

By G. W. Sherwood, Civil Engineer.

Mr. Manson's able and comprehensive paper† leaves little to be said with regard to the historical and economic features of the subject, and I desire here to express my unqualified approval of his opinions with regard to *strict* and exclusive governmental construction and ownership of the canal.

The plans for the construction of the canal have been chiefly evolved from the information obtained from surveys made under the direction of Chief Engineer Menocal since 1887, except with regard to the river division from Ochoa to Lake Nicaragua, which I believe are based upon older surveys.

In 1889, the plans were submitted to a Board of Consulting Engineers, which submitted a report, in May of that year. This report was published in *Engineering News* of December 15, 1892, and furnishes an authoritative exposition of the plans and estimates.

Quoting from this report: "The project in detail consists of the following elements:

"(1) Of 10 miles on the east, and 0·57 miles on the west end, of sea level canal dredged in from the coast.

"(2) Of a flight of three locks on each end, all within a distance of about one and one-half miles at one end, and of two miles at the other, by which the ascent is made from the sea level to the summit of level of 110 feet (this elevation being some four feet less on the eastern end, to allow for a necessary fall of three-fourths of an inch per mile in the San Juan River). These locks are shown by the borings submitted to be all founded on rock. The proposed

* Abstract of a paper read before the Technical Society of the Pacific Coast, June 1, 1894, and revised by the author for publication in the *Journal of the Franklin Institute*.

† *Vide*, Transactions Tech. Soc. Pac. Coast, July, 1893.

size for locks, 650 feet by 70 feet by 30 feet deep, seems sufficient for all demands.

"(3) Of a very long summit level of 155·98 miles, consisting of four main parts:

"(*a*) The great divide cuts of three and eight miles in length, respectively, which are shown, by the evidence submitted, to consist chiefly of rock, overlaid with a few feet of earth.

"(*b*) The Deseado, San Francisco, Machado and Tola basins, formed by dams, furnishing 21·57 miles of slack water navigation, 18·13 miles of which require no excavation, and the remaining 3·44 miles earth dredging only.

"(*c*) The River San Juan, raised in level by a dam at Ochoa, so as to furnish slack water navigation, and Lake Nicaragua, furnish together 121 miles of free navigation, of which 36·5 miles require some earth dredging, and 3·83 miles some rock dredging.

"(*d*) An inconsiderable amount (1·63 miles) of canal section in earth, chiefly to connect the San Francisco and Machado basins."

There is evidently an error under the second heading, as the necessary elevation would not be attained by three locks thirty feet deep.

From another source, the information is obtained that Locks 1, 2 and 3 on the east are to have a lift of 30, 31 and 45 feet, respectively; Locks 3 and 4, 42·5 feet each, and Lock 6, a maximum lift of 29 feet at low tide.

In addition, the harbor at Greytown must be reopened; and a harbor constructed at Brito, the western terminus, which is, at present, an open, unprotected roadstead.

The work of construction was begun in 1889, by the Nicaragua Canal Construction Company, under contract with the Maritime Canal Company, and their efforts have been directed chiefly toward reopening the harbor at Greytown. In 1889, the opening from the harbor to the sea had become entirely closed, and the only access to the lagoon was through the mouth of the Rio Colorado, twenty miles below, and an inside channel. A strong current setting westward along the coast, laden with silt from the Rio

Colorado, and assisted by the prevailing winds and heavy surf, is believed to have been the most active agent in closing the entrance. In December, 1889, the construction of a jetty, to the eastward and windward of the old entrance, was begun ; and it was gradually extended, until it is now reported to be about 1,000 feet in length. The jetty is 14 feet in width, built of creosoted piles, in bents of twelve piles, eight feet apart, with 14-inch by 14-inch caps, and strongly braced. The spaces between the bents on each side are filled with a row of piles, driven close together. Brush matresses, laden with rock, were sunk in the interior, which soon became filled solid with sand. All the piles and timber for this structure were imported from North Carolina. The creosoted piles have, I believe, been found to resist the action of teredo very well.

With this assistance the channel again broke through, and gradually deepened to about six feet on the bar in June, 1890, since which time it has been used entirely in the commerce of the port.

It was confidently predicted that, with the aid of the dredges which were purchased from the Panama plant, a depth of at least twelve feet would be readily obtained in the channel, but the beneficial effect of the jetty appeared to cease when a depth of between six and eight feet was obtained, and the dredges were found to be unable to work in the heavy surf.

The plans for the future, it is reported, contemplate the construction of a jetty on the other side of the entrance, and the digging out of the channel by dredges suited to the work. The success of this portion of the work does not appear doubtful, but will probably prove very costly, and, perhaps, entail a heavy expenditure for maintenance. The conditions affecting the work are the strong current before mentioned, rapidly filling the angles between the existing jetty and the shore, a very small rise of tide, not more than eighteen inches at most, with a small area of tidal basin, and, during the greater part of the time, a rough sea and heavy surf.

It is unlikely that any difficulty will be found in excavat-

ing the sea-level portions of the canal. This can be done with the dredges alone, as has been proved at Panama, and its cost narrowly approximated. A section about a mile in length and sixteen feet deep has been already completed without difficulty.

The locks on the eastern side have, I believe, been relocated since the report of the Board of Consulting Engineers was made, and I understand that a rock foundation is not obtainable for them. The borings show strata of clay and gravel with boulders, but no rock is found at a practicable depth. The great rise of Lock No. 3, forty-five feet, more than three times as great as any now in existence, would seem to place it in the category of experiments. But, perhaps, the mechanical resources of the age will be equal to the emergency. The locks will be built of concrete.

The great divide cuts contain the bulk of the material to be moved, other than that to be excavated by the dredges, and it is chiefly rock. This is a favorable condition, as steeper slopes will be permissible, and this material will, perhaps, be more easy to move than the heavy clay which is found thereabouts, owing to the enormous and constant rainfall of that region.

The most daring and dangerous feature of the plans for the canal is found in the great basins; and to withdraw from obscurity the facts concerning the difficulties that beset the work of constructing them, is the writer's excuse for venturing upon this well-worn subject.

The Cano Deseado on the east, and the Limpio, a branch of the Cano Chanchos, on the west, head nearly together on opposite sides of the pass that is to be utilized for the Eastern Divide cut. To form the basin of the Deseado, a dam, 1,050 feet long and 70 feet high, must be built across its valley at Lock No. 3. In addition, gaps in the surrounding ridges, aggregating over a mile in length, must be filled with embankments of varying height.

From the other, or western, side of the divide, a low ridge extends to Ochoa, a profile of which may be found in the supplement to *Engineering News* of September 14, 1889. It is Profile "D." By filling the gaps in this ridge, the San

Francisco basin will be formed. This ridge is cut by three considerable streams, the Chanchos, the San Francisco and the Peary, flowing southward into the San Juan; and there are many other gaps in the ridge falling below the elevation of the summit level, so that the dams necessary to fill the depressions in this natural embankment aggregate nearly eight miles.

The Machado Basin, to be made by a dam across the San Juan at Ochoa, occupies the valley of the Cano Machado, which is separated from the valley of the Rio Peary by a narrow ridge. The dam across the San Juan at Ochoa is projected to be "1,250 feet long, with abutments of 650 feet, and 61 feet high."

The valleys of the three streams above mentioned are each about one-fourth of a mile in width, and, where the embankment line crosses, have an elevation of about 50 feet above sea-level. This will necessitate dams at least 60 feet in height. There are several other depressions of equal depth from 300 to 600 feet wide. The remaining gaps will require embankments of varying height. The borings reveal that the alluvial deposit of the valleys is underlaid by clay, but no underlying strata of rock have anywhere been found.

The embankment line crosses the Rio Peary where it issues from a large morass known as the Florida Lagoon. The surveying parties were accustomed to cross the marshy places near the river by bending over the tall grass and walking upon it; and upon the site of the proposed dam at this point, a pole has been pushed down forty-five feet by the mere pressure of the hand.

The plans for the construction of these dams contemplate the building of a double-track railroad along the embankment line, at the level of the top of the embankments, from the divide cut westward to Ochoa, and across the river; and eastward, to the Deseado embankments. The dams are to be built of loose rock brought from the divide cut by this railroad. The dams in the larger depressions, according to published reports, are to have a base of 500 feet and a width of 25 feet or more on top.

The Board of Consulting Engineers has stated in their report, with regard to this feature of the plans, as follows:

"There is the possible hazard, in respect to the San Francisco and other basins, that they may not prove sufficiently retentive, owing either to leakage around the ends, or under the bases of the dams and embankments, or to concealed permeable strata beneath the natural surface. We deem this a remote danger, since both the surface and subterranean formations, so far as revealed by borings and by the reports of the observations of reliable men, familiar with the locality, are favorable.

"For a work of ordinary magnitude, we would accept such evidence as ample; but, in view of the great area and volume of the basins, we agree that the possibility ought to be covered by the estimate. The probability is great that there are no permeable strata beneath the surface; if they exist, they might not necessarily cause leakage; and even if leakage resulted, it would not necessarily do serious harm. Concentrated leakage, if it occurred, *might possibly* be remedied, and if it should develop at all, would be likely to occur at an early stage of the work of construction. The worst result to be feared is, that it might compel a modification of the original features of the project, enforcing a lowering of the water-level at certain points, and at an additional cost of about $7,000,000."

This last statement would have been much clearer if it had explained what modification of the plans is possible, resulting in a lowering of the water-level at certain points, and where those "certain points" are located.

It is difficult, also, to understand why leakage should develop "at an early stage of the work of construction," for it surely cannot be intended to allow the basins to fill until the dams are nearly or quite completed, with only one railroad to carry the material.

This method of dam construction upon such foundations and under the conditions that prevail there, will, no doubt, prove a revelation to the hydraulic engineers connected with this Society. There is, so far as I know, no precedent for such works under such conditions. Yet this

is the vital feature of the plans. The basins would dispose of the objection always urged against this route, the necessity of numerous locks, and also of the tremendous problem of cross drainage east of Ochoa.

Even supposing the dams can be built in this manner, there still remains a problem of at least equal difficulty to be dealt with, the construction of wasteways to provide for the overflow of the San Juan, a river of great volume, and the several smaller streams.

The wasteways cannot be placed in the native rock, or upon a rock foundation, for there is none between Ochoa and the divide cut.

It certainly cannot be considered any slight problem to conduct a river like the San Juan, whose mean flow at the Lake is 14,924 cubic feet per second, according to Mr. Manson's authority, and at flood much greater, down a fall of sixty feet or more, without any rock foundation for the works. I have, however, never seen this matter referred to in any reports or discussions on the canal project; and the Board of Consulting Engineers have not touched upon it.

It must be taken into consideration that the dams and wasteways must be built to last forever. It will never be possible to drain the summit level for repairs, because of its enormous volume, without stopping the canal service for many months; and I do not understand that any provision is to be made for such a purpose. Should a wasteway be undermined, or the smallest embankment give way, a long time must elapse before repairs could be made.

The rock in the divide cut is soft and rotten, and will rapidly disintegrate under the conditions existing there. It is useless for construction purposes.

The writer is of the opinion that the dams and wasteways cannot be built, in the manner contemplated, so as to permanently resist the forces tending toward their destruction; and that if the canal is built, it will be necessary to modify or eliminate these features of the plans.

The difficulties that will attend the work of construction between Ochoa and Greytown are appalling. This whole region is a dense jungle of tangled vegetation, and much of

it is a loathsome morass. There are no roads, or any possibility of maintaining any, on account of the enormous and almost continuous rainfall, which cannot be less than 400 inches per year. Not a stick of timber or a block of stone suitable for construction purposes exists there. Even the ties used for the railroad already built were brought from Louisiana.

The Canal Company purpose attacking the problem by building a "low-grade" railroad from Greytown to Ochoa, following the canal line to the divide and the embankment line from there to Ochoa, but a lower level than the railroad on the top of the embankments, on the southerly side of the ridge, and in the bottom of the valleys, to be used for construction purposes. A section of this railroad, reported to be eleven miles in length, has been built from Greytown across the swamp, and the location made to Ochoa.

The construction of the road across the swamp was a matter of some difficulty. The roadbed was corduroyed with the timber cut from the clearing, and upon this foundation the ties and rails were placed.

The work train, loaded with sand from the canal section near the lagoon, by a steam shovel, was backed in and unloaded by a ballast unloader; and thus a permanent embankment was gradually built up. The construction of the railroad by this method was necessarily very slow. Five months were occupied in the construction of four miles.

With the aid of the low-grade road, the line along the top of the embankments, or the "high-grade" railroad, will be built, which is intended to be maintained permanently.

It will be impossible to make wagon roads, or to use wheeled vehicles of any kind in this region, because of the almost constant rainfall, turning the soil to mud, even if cattle of any kind could live there, which is doubtful. When there is added to this the fact that every stick and stone must be brought in from some outside source, some conception may be formed of the tremendous difficulties to be encountered, and of the enormous expense of work carried on under such conditions.

The climate, except on the beach where the constant

breeze makes the heat more endurable, closely resembles that of the fernery in the conservatory at Golden Gate Park. In the tangled depths of the jungle no breeze is ever felt. Any considerable exertion causes the most profuse perspiration and induces great fatigue. The surveying parties were housed in "shacks," structures consisting of a roof of palm leaves, supported on crotched poles with sides and ends open.

Communication was maintained with headquarters, near Greytown, by steel canoes on the various streams, and the steamer line on the San Juan.

The field work was of the hardest and most disagreeable description. Work never stopped on account of rain. Each instrument man was accompanied by an umbrella-bearer, who protected the instrument as well as possible. The heat was too great to allow of wearing rubber garments, and consequently everyone was continually wet through. This, however, was not especially disagreeable, as it was always warm. Frequently, it was necessary, for days at a time, to wade about in swamps, in mud and water up to the waist, or deeper. The most intense discomfort is caused by mosquitoes, and the only refuge for them is beneath the heavy calico mosquito bar, at night. Innumerable other varieties of insects and reptiles aid the mosquitoes in their work of torment. Nearly all who have been in the jungle for any length of time are afflicted with skin disease similar to ringworm, supposed to be caused by some insect, and for which there has been found no remedy which can be depended upon to cure while the victim remains in the country.

That life, under such conditions, is not conducive to health, is apparent. Nearly all suffer from malarial fevers, though a few escape and others appear to become acclimated. Other frequent disorders are dysentery, boils and a form of gastritis, which causes the victim to vomit for several hours at a stretch, and which leaves him completely prostrated.

There does not seem to be any great difference between the health conditions at headquarters on the beach and in the forest of the San Francisco basin. It was always a

mooted point which was the healthier, or perhaps I should put it, the more unhealthy, locality.

The labor problem is one of the chief difficulties to be solved. The employment of Chinese, who would probably be most efficient on this work, is prohibited by the concession. It is expected that the unskilled labor supply will be drawn from the negro population of Jamaica, and the other West India Islands. The native population make excellent boat crews, and axe-men for the surveying parties, but have an unconquerable aversion to the rougher forms of manual labor, so that little can be expected from them. It will probably be found that, as at Panama, an inferior class of labor must be employed at high wages.

Another obstacle to be met is the possible advent of yellow fever. It would be a miracle if the work should be completed without an outbreak of this dreadful scourge.

On the western division, the conditions, as at Panama, are more favorable. The physical obstacles are less, the climate more healthful, and the rainfall not so large or continuous; and the Tola basin can be eliminated, if necessary.

It would seem that there are here no obstacles that cannot be overcome by an intelligent application of sufficient money.

It will be observed that the Board of Consulting Engineers has raised the estimate of cost from $65,000,000 to $87,800,000.

That it is exceedingly difficult to make a reliable estimate of a work of so extensive a character, even under the most favorable conditions, the Manchester Canal affords evidence. If it is not possible correctly to estimate the cost of a work in a country like England, where the cost of everything necessary is known, the labor supply reliable and efficient, the climate healthful and invigorating, and all the conditions favorable, it is certainly not possible even to approximate the cost of such gigantic work in an unhealthy tropical country, lacking utterly in materials of construction and in efficient labor supply.

Panama furnishes the only precedent for estimates, and the information obtainable from that source is not reliable

or encouraging. From the information obtainable there we can learn only that high wages must be paid for labor which is rendered inefficient by the unhealthy conditions, and the physical impossibility of men doing the same amount of work as in a temperate climate.

That the completion of the canal would be of vast benefit to the commercial interests of the Pacific Coast and the world in general, does not admit of doubt. It is equally certain that a failure, such as the French have made at Panama after the expenditure of an enormous amount of money, would be exceedingly disastrous; and it behooves the American people to insist that the project be proved feasible before they allow their credit in any manner to be pledged to this enterprise.

The bill of the Representative from Washington, to appoint a committee to make inquiry into the matter, is a step in the right direction, provided that the services of a board of competent and disinterested expert engineers are employed.

It is undeniable that the only information we possess concerning the practicability of the route has been collected by the officials of a company who are interested in foisting their scheme upon the Government; and who naturally do not lay any great stress upon the unfavorable features. There is no doubt that the maps in the possession of the company are very accurate, and that the quantities have been calculated with sufficient care. That the conclusions which have been drawn from these data are also correct, is a matter into which careful examination should be made.

Much has been said of the naval advantages that would accrue to the United States from the construction of the canal under Government control, and from the possession of a naval station in Lake Nicaragua. To the thoughtful observer, this must seem doubtful. In the first place, no naval station in Lake Nicaragua, or in any other portion of Nicaragua, has been, or is likely to be, granted to this Government. The control of the canal would involve its protection. The United States is not at present in a position to insure this, and the problem might involve very serious difficulties.

The canal, if built, should be dedicated to the interests of peace, and its neutrality be guaranteed by the great commercial nations of the world. Would it be too great a stretch of the fancy to image the great maritime nations of the world uniting to construct this work so beneficial to all, each contributing a just proportion of the expense, according to the benefits that it would receive?

Let the waterway be made free to the commerce of the world, except for sufficient tolls to provide for its maintenance; and its usefulness be not impaired by any attempt to make it pay interest on its cost.

The brotherhood of nations is not an unattainable dream to this generation. Might not the construction of this great work in such manner be the first step toward a union of the civilized races; and hasten the day when the world shall have forgotten the art of war, and when the nations shall dwell together in peace?

ADDENDUM.

Since this paper was written, the New York *World* has published (May 2, 1894) a letter from a special correspondent sent to Greytown to ascertain the condition of the canal company's affairs.

This letter is very interesting, as it furnishes information relative to the effect of time on the works already constructed; and enables an opinion to be formed as to their probable efficiency.

It is stated in the letter that the channel has filled up so that a vessel drawing only three feet of water was wrecked while trying to enter the bay, and that the *Presidente Carazo*, a small steamer, formerly running between Bluefields and Greytown, and which could get out with six feet of water on the bar, has been imprisoned for six months. It is also stated that the piles in the jetty are "rotten and loose."

The testimony of engineers familiar with the subject would seem to indicate that piles properly creosoted will resist the action of the *teredo navalis* for a long time. If not properly creosoted, their life is very short.

The cause of the filling up of the channel is probably that the angle between the jetty and the shore has become filled up, and that the sand is now flowing around the end of the jetty, and not through a breach in it.

If this is so, it possibly may not matter if some or most of the piles are honeycombed, as the new land formed in the angle would ward off the most destructive forces, and the weighted mattresses with which the structure was filled, assisted by the piles that must be yet unharmed, might still be sufficient to preserve its usefulness. It is probable that the depth of channel before obtained can be regained by merely extending the jetty.

The correspondent has evidently been imposed on by the "American merchant," who told him that it was the plan to turn the water of the San Juan River through between the jetties. This would be an undertaking almost equal to building the canal, besides being useless. The small branch of the San Juan that enters the lagoon has almost no current for many miles from its mouth, and has already filled up a large portion of what was once the harbor of Greytown. It is the intention to cut off this branch at its head; and, as has been stated before, to dredge out a channel between the jetties.

The roadbed of the railroad is said to have sunk beneath the swamp in places, and to be overgrown with weeds. This is what might be expected. The growth of vegetation in this natural hot-house is marvellous, and can only be kept down by constant labor.

The five dredges, for which $600,000 was the reported price, are said to be sunk in eight feet of water. They represent a dead loss, for which the company would no doubt like to be reimbursed by this Government. All the machinery and supplies on the ground are rapidly becoming valueless—are, in fact, rotting.

The length of canal section dredged is stated to be one-half a mile, fifteen feet deep, which has been partially filled up again by natural agencies. This would indicate that some sort of protection for the banks will be necessary, for the sea-level section at least

The account of the manner in which the property of the company has been seized and sold to satisfy its debts, is interesting and instructive. It emphasizes what was hinted at in my paper—that this Government, if it builds the canal, must be prepared to protect its interests there with a strong hand, for it will certainly be necessary while present conditions of government prevail in those countries. The most ardent friend of the canal must regard with uneasiness the construction at such an enormous expenditure of a waterway vulnerable in a thousand places, through a country subject to an unstable government, founded upon the principle that might is right— a country remote from the centers of civilization—unless the work is under the protection of a power that will deal promptly and surely with any infraction of the terms of concession, allowing no quibbling over details.

The statement that the Nicaragua Steam Navigation and Trading Company belongs to the Maritime Canal Company, again "bobs up serenely." The assertion is so often made that this company belongs to one or the other of the canal companies, that a relation of the facts in the case would seem to be in order.

The Nicaragua Steam Navigation and Trading Company possesses a monopoly of the steam navigation of the San Juan River and Lake Nicaragua, and owns a number of steam vessels. The greater part of its stock was purchased by individuals, (who, it is said, were chiefly officials of the canal companies) before the Construction Company began operations; some interest, one-third, I believe, being retained by its former owner. This company leased the tug *Milliard* and lighters belonging to the Construction Company, and did all the lightering and transportation generally for the latter company. It also maintained a supply store at "headquarters," and, by a convenient system of credit, largely absorbed the pay of the negro laborers, to the great disgust of the merchants of Greytown. But it is not known that any of its profits were ever turned into the coffers of either of the canal companies.

LIGHTNING ARRESTERS, AND WHY THEY SOMETIMES FAIL.*

By Alexander Jay Wurts.

The lecturer was introduced by Prof. E. J. Houston, of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

When the first telegraph lines were installed it was noticed that the instruments frequently became damaged during thunder-storms. The wires were charged with static electricity, which, instead of following many turns of wire through the instrument to earth, would puncture the insulation between consecutive convolutions and thus short-circuit the coils. Besides this damage to the instruments, it was noticed that the static charge would sometimes spring from the line, or other metallic parts of the circuit, to neighboring conducting objects, such as nails, iron pipes and the like. It was also noticed that, when discharge occurred in this manner, the instruments were not damaged. In other words, these neighboring objects formed by-paths for the discharge and, in a measure, offered protection to the instruments. As a consequence of such observation, artificial by-paths were constructed, which consisted of two metal electrodes, separated by a small air space. One of these electrodes was connected to the line, the other to earth; and thus the first "lightning arrester" was constructed.

It was then supposed that, when a line was provided with a "lightning arrester," the instruments would be "protected against lightning." The result, however, proved this conclusion to be erroneous. The discharges would sometimes pass to earth over the spark-gap of the lightning arrester, but not infrequently would quite ignore the arrester and, as before, puncture the insulating material of the

* A lecture delivered before the Franklin Institute, March 15, 1895.

instruments. In other words, the discharge was selective. The failure of the lightning arrester was a vexation; but at that time, owing to the small amount of apparatus in use, the damage reckoned in dollars and cents did not call for any special study of the reasons for the selective character of disruptive discharges. In these days, however, the vast amount of capital invested in electrical apparatus of various kinds, and the consequent increased annual loss directly due to these disruptive discharges, have called for a thorough investigation of the subject and the designing of more efficient means of protection.

It is a very significant fact that overhead wires, after being subjected to the influence of thunder-storms, do not show the damage to insulation which one would reasonably expect to find had the wires been actually struck by the lightning discharge. It is not uncommon, however, to hear of wires being "struck by lightning;" in fact, linemen will frequently volunteer to point out the exact spot where the lightning entered the wire. But, so far as I have been able to learn, overhead wires are not struck by lightning. The points usually selected by lightning discharges are trees, lightning-rods, church steeples, tall chimneys, and the like. There seems to be no reason why lightning should strike a horizontal wire, especially when it is insulated from the earth.

Overhead wires may become charged in three ways and combinations of these, viz.: by static induction from the clouds; by dynamic induction from a lightning discharge, and by conduction from the surrounding charged atmosphere. The writer inclines to the theory of conduction.

During thunder-storms, and in many instances during fair weather, the atmosphere becomes charged with electricity at a constantly increasing potential as we recede from the earth. At the top of Washington Monument, Washington, D. C., a potential of 3,000 volts has been measured during thunder-storms, and at the top of the Eiffel Tower a potential of 10,000 volts has been measured. Now, it is well known that lightning is oscillatory. The first oscillation, or discharge, makes a crack or hole through

the atmosphere, and through this the succeeding oscillations take place. About ten to twelve oscillations can be observed, and the time interval is reckoned at about ·00001 of a second. The lightning, therefore, being oscillatory and the atmosphere charged, if an overhead wire be charged by conduction from the atmosphere—that is, become electrically a portion of it—then, with every lightning discharge it would seem as though the potential of the atmosphere would sympathize with the oscillatory character of the lightning, and that the charge in the atmosphere would also oscillate and produce oscillations in overhead wires; and, in fact, in all metallic conductors, such as wire fences, rails, etc. The fact that wires become heavily charged during fair weather offers further evidence that they are charged by conduction from the surrounding charged atmosphere. In some instances, lightning arresters have been known, during perfectly fair weather, to discharge overhead wires at the rate of 140 times a minute.

In any case, whatever the method of charging may be, the discharges from overhead wires seem to be oscillatory, and during thunder-storms they are, in most cases, simultaneous with lightning flashes.

If we raise one end of a trough of water and then quickly lower it, the water will quietly surge back and forth. If, when the water is returning, we again raise the same end of the trough, a wave will be started forward, which, meeting the returning wave, will combine or collide with it, causing a piling up of the water at that point. Further complications may be introduced by repeatedly, and at proper intervals, raising and lowering one end of the trough. If the crests of these waves be carefully examined, it will be noticed that they differ in height and are constantly shifting their positions.

During thunder-storms the static electricity in overhead conductors surges back and forth very much as the water in a trough, and the indications are that electric waves are set up which combine and interfere with each other in such a manner as to produce frequent and unequally distributed points of high and low pressure. The ends of wires are

points of reflection, and at these points the pressure is always great. Whatever may be the true explanation of the apparent idiosyncrasies of disruptive discharges, it is, after all, with facts that we have to deal.

Referring to *Fig. 1*, let *A A* represent the terminals of a static induction machine *L*, a battery of six one-half-gallon Leyden jars, *B*, a spark gap of $\frac{12}{32}''$, and *C*1, *C*2, etc., variable spark gaps, and let the connections be as indicated. With discharges at *B*, discharges will also occur at one or more of the gaps *C*1, *C*2, etc. When *C*1, *C*2, *C*3 are equal, the discharges occur across these gaps indiscriminately. When discharge occurs over small gaps in the neighborhood of *C*1 or *C*2, thread-like discharges are always noticed at *Cn*. And even when *Cn* is increased to $\frac{17}{32}''$ the thread-like discharge is still noticeable with every discharge at *C*1 or

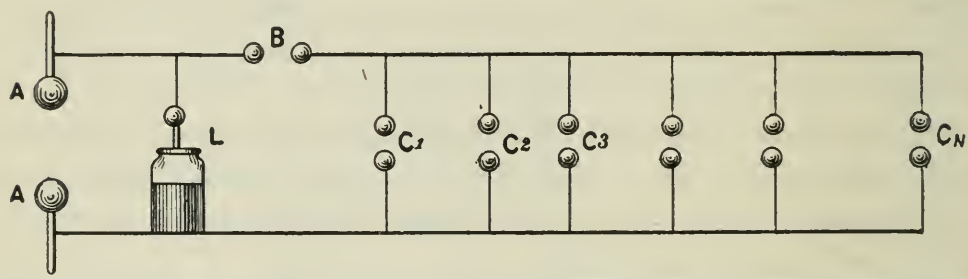


FIG. 1.—Experiment with line arresters, illustrating selective character of discharge.

*C*2. If a large number of spark-gaps, varying among each other as much as 100 per cent., be distributed as *C*1, *C*2, *C*3, etc., discharges will still occur indiscriminately, sometimes across a large gap, sometimes a small one, sometimes across three or four consecutive or widely distributed gaps. When *C*1 is equal to $\frac{5}{32}''$, *C*2 equal to $\frac{17}{32}''$ and placed two, three or more feet away from *C*1, and if *C*3, *C*4, etc., be omitted, then a discharge will occur at *C*2 once in about 500 times without any discharge at *C*1. These experiments demonstrate the selective character of the discharge. If, however, *C*2 be increased to $\frac{18}{32}''$, the discharges will cease altogether at that point, and this last experiment indicates the limit of range over which selection *may* take place under the conditions given. But it is perfectly evident that with a large number of gaps, the probability of discharge across any

one gap is very much less than if only two gaps were present. In other words, if $C1$ represents a piece of apparatus which we desire to protect, the protection will be greater as we increase the number of spark-gaps, $C2$, $C3$, etc., but in no case can there be certainty of protection unless the gap $C1$ be relatively so large—or, more broadly speaking, unless the path $C1$ offer such a high resistance to the passage of disruptive discharges—as to place it beyond the limit of selection. The apparatus which we have used in the above experiments is different from that employed by nature; the results, however, so far as my observations go, are identical, and the lesson to be learned is simple; it is this: the probability of damage to electrical apparatus connected to overhead wires is lessened as we increase the number of opportunities for discharge from the line.

In summing up thus far, we notice briefly that the line becomes charged, surgings are set up, there are points of reflection which are always points of great electrical strain, there are points along the line of varying intensity or tendency to discharge, these points are constantly shifting their positions, and spark gap lightning arresters are used to conduct disruptive discharges to earth.

The lightning arrester of to day, as a protective device, differs from the lightning arrester of the early telegraph in detail only. A simple spark gap, one terminal of which is connected to the line and the other to earth, is essentially the lightning arrester now in use. But, with the modern high-potential circuits, it is found that the dynamo current follows the static discharge across the spark-gap of the arrester, causing thereby a short-circuit or dangerous ground on the line. In order to avoid this difficulty, arc-rupturing devices are attached to the lightning arrester, which have for their function the immediate interruption of the dynamo current, without interfering with the further operation of the lightning arrester as a discharging device. "Automatic Lightning Arresters," as they are called, differ among one another in the various means adopted for rupturing the dynamo arc. But the arc-rupturing attachment has nothing whatever to do with the apparatus as a lightning arrester,

so that although automatic lightning arresters vary in outward appearance, and are in general more cumbersome and expensive than the original simple spark-gap arrester, yet, as lightning arresters, they are nothing more than spark-gaps. Various lightning-arrester attachments have been designed for the automatic rupture of dynamo arcs, but owing to the very high potentials which are so often used, they are found to be not only undesirable, but inefficient, the lightning arresters being frequently destroyed by the vicious dynamo arc.

In practice, however, complaints are not so much that lightning arresters are destroyed as that they "fail to protect." It is not unusual to see several different kinds of lightning arresters in a single station, which have evidently been installed with the idea of determining which one of them would prove the most efficient. But such experiments have met with disappointment, for the reason that sometimes one lightning arrester, and sometimes another, would receive the discharge, and the selective character of disruptive discharges was not understood. The failure of lightning arresters is not due to the particular *kind* of lightning arrester, or to the patent under which it is manufactured; it is due largely to the peculiar conditions with which it has to contend, namely, that the discharge is selective, and that, in order to protect apparatus, means must be taken to control these selections, or, at least, to provide so many paths to earth that the probable selection will be one of the many paths provided. In other words, lightning arresters do not "protect," they simply offer opportunities for discharge. These opportunities may or may not be embraced, according to circumstances. But the failure of lightning arresters is not altogether due to the peculiar conditions already referred to. Poor ground connection, inductive resistance in the ground circuit, defective insulation in the apparatus to be protected, and a general misunderstanding of the subject, are not infrequently the cause of serious losses which might otherwise have been avoided.

We have noticed that lightning arresters do not "protect," that they simply offer opportunities for discharge. We

have also noticed that discharges do not pass readily through coils of wire—coils therefore protect. Properly constructed choke coils, connected in the circuit, offer a high resistance to the passage of disruptive discharges, and when used in connection with lightning arresters the combination offers a very reliable means of protecting well-insulated apparatus against lightning. Laboratory experiments, together with tests made under actual working conditions, indicate the advisability of using four choke coils in series, in each wire, with four lightning arresters intervening, as shown in *Fig. 2.* This arrangement is more particularly suitable for the protection of station apparatus. Coils can, however, be used to advantage on the line for the protection of the more expensive translating devices.

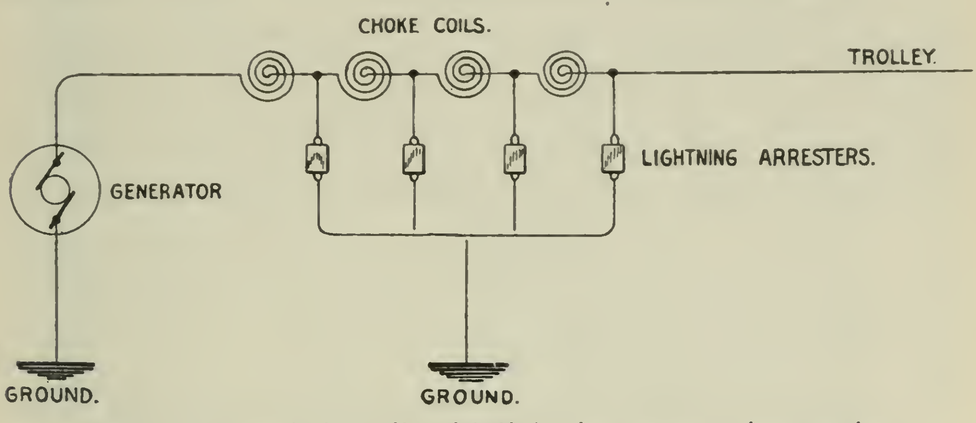


FIG. 2.—Four choke coils with lightning arresters intervening.

The general construction of a choke coil is a matter of considerable importance. A flat spiral possesses some advantages over the helix, but for practical purposes these hardly compensate for the lower cost of the latter, which, for best results, should be wound over a wooden or other non-conducting core. Metal cores and cases should be avoided, because the induced currents in these parts would lower the choking effect of the coils. The number of turns which can be used to advantage is limited. It is found by experiment that, with given conditions, the choking effect increases with the number of turns up to a well defined critical point, after which additional turns fail to have any appreciable effect. It is probable that these critical points vary with the amount of electricity discharged; that is, for heavy

discharges the critical point for maximum choking effect would embrace a larger number of turns than would smaller discharges, and the choking effect for a given number of turns within the critical point would also be greater for heavy than for small discharges. For practical purposes the writer recommends from forty to fifty feet of wire wound either into a flat spiral having an internal diameter of three inches, or into a three-inch helix with a single layer.

Summing up once more, we note that wires become charged, that lightning arresters offer opportunities for discharge, and that coils protect. Bearing in mind these three points, let us note that, with the extensive systems of electric light and power distribution now in use, it would be quite impractical to install the above-described system of choke coils and lightning arresters for the protection of each separate piece of apparatus. The first cost of such an installation would be prohibitory. It is evident, therefore, that the protection of line apparatus with choke coils being excluded there remains but one alternative, namely, that of providing such a large number of opportunities for discharge, distributed over the entire system, that the selection of the discharge will be one or more of the paths provided for it. In other words, *line arresters* connected at frequent intervals offer the only practical method of protecting widely distributed apparatus. But, in order that such an installation may prove satisfactory from a commercial as well as an operative standpoint, the arresters must be cheap, simple, free from moving parts and perfectly reliable without the necessity of regular inspection.

Realizing that these points were not covered by any one of the many automatic lightning arresters which had already been devised, I undertook to simplify the problem, and in my early experiments proposed to equip the lines of electric systems with a multiplicity of spark-gaps, and, at the station, to provide an automatic circuit opening-and-closing device, which, upon the formation of a short circuit across one or more of the spark-gaps on the line, would instantly open and then immediately close. While experimenting with

this system, I discovered that if the electrodes of a lightning arrester were made of zinc, the short-circuiting arc, which had heretofore threatened the life of the lightning arrester, absolutely failed to be maintained. In other words, zinc proved to be what is now commonly known as one of the "non-arcing" metals. Subsequent investigation disclosed the fact that there were four other metals which exhibited similar characteristics, namely, bismuth, antimony, cadmium and mercury.*

The discovery of the non-arcing metals at once solved

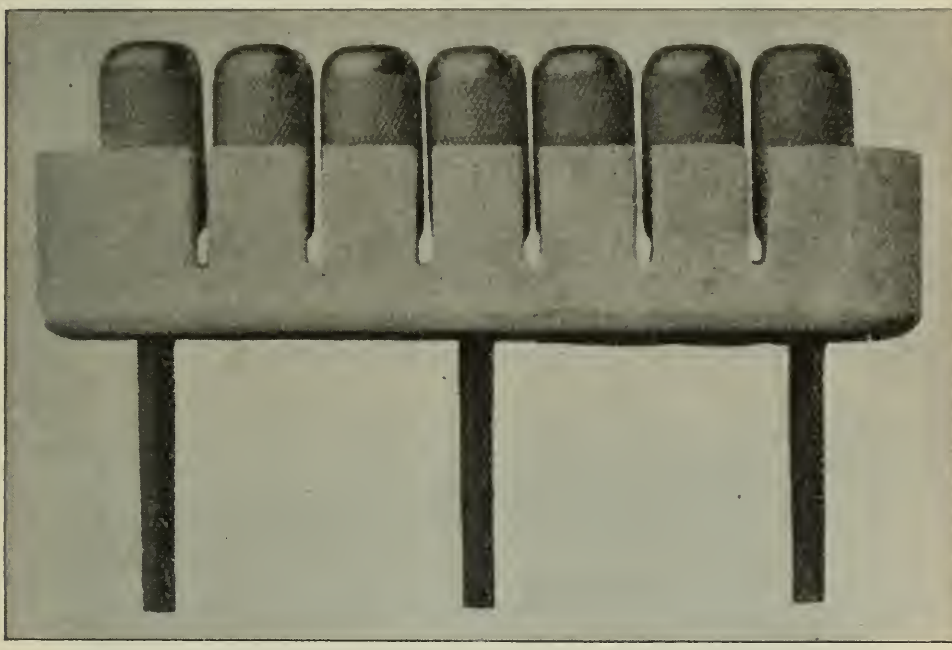


FIG. 3.—Double-pole non-arcing metal line arrester.

the problem of a lightning arrester adapted to the requirements of alternating current circuits, and which would meet the conditions already enumerated.

The non-arcing metal lightning arrester, which is illustrated in *Figs. 3, 4* and *5*, consists, as will be seen, of seven non-arcing metal cylinders, insulated from each other, each one and one-half inches long and three-fourths of an inch in diameter. When installed, the two outer cylinders are

* A full description of the researches and experiments which led to the discovery of the non-arcing metals is given in the *Transactions of the American Institute of Electrical Engineers*, for March 15, 1892.

connected to either leg of an alternating current circuit and the central cylinder to earth, thus forming a double-

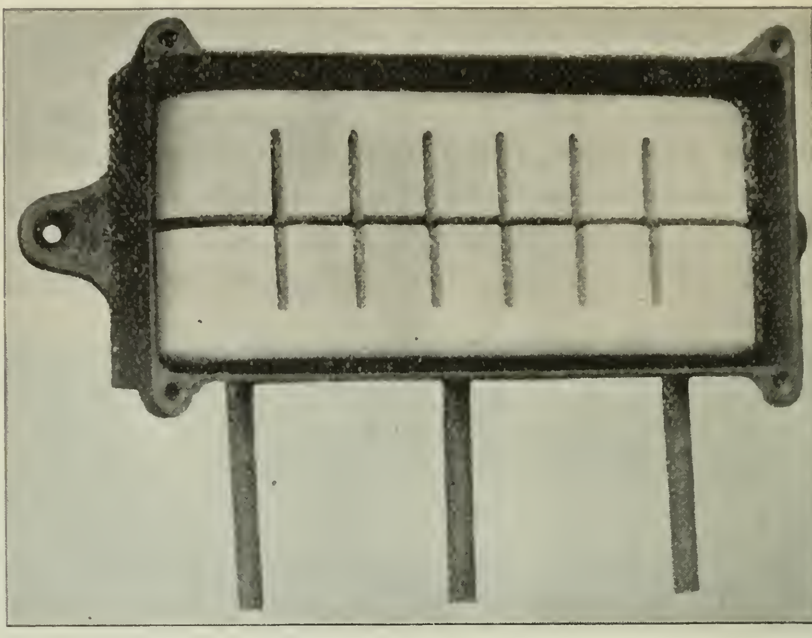


FIG. 4.—Non-arcing metal line arrester.

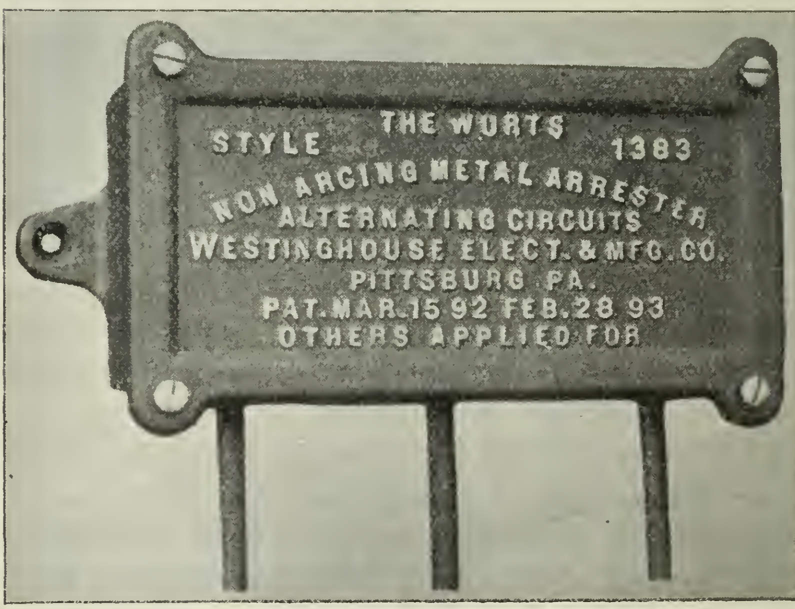


FIG. 5.—Non-arcing metal line arrester.

pole lightning arrester. In practice, these are manufactured in units for 1,000 volts, so that for 2,000 volts two are con-

nected in series, for 3,000 volts three are connected in series. The diagrams in *Fig. 6* indicate the connections for each potential. There are many thousands of these lightning arresters in actual service, and the experience of three years has fully demonstrated that they are perfectly reliable without the necessity of regular inspection. The simplicity of the device is at once apparent, and the cost to the user is a mere fraction of what was formerly demanded for the best types of automatic lightning arresters. It will thus be seen that, at least for alternating current circuits, the requirements of a commercially serviceable line lightning arrester have been fully met.

The success of the non-arcing metal lightning arrester was such that I was induced to make further investigations

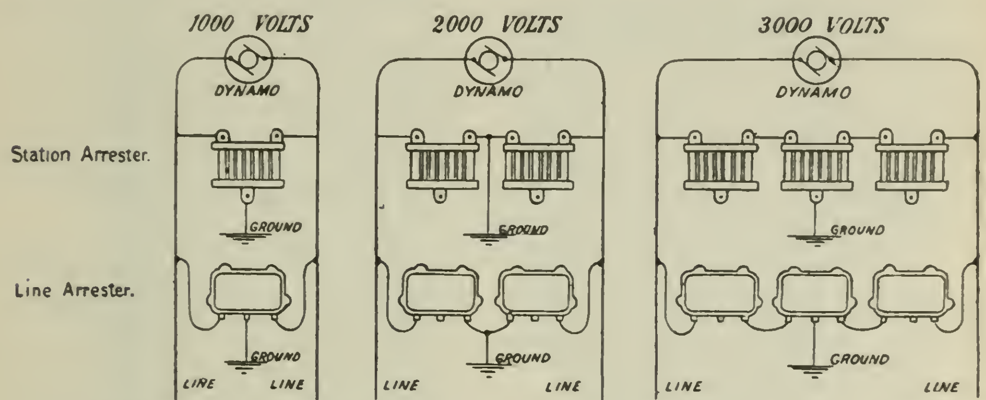


FIG. 6.—Diagrams for lightning arrester connections on circuits of different potentials.

as to the possibility of constructing an equally simple and efficient device for use on direct current circuits. In view of the many experiments which I had made with almost every kind and combination of the ordinary metals, I had become convinced that I should not be able to construct a non-arcing lightning arrester for direct current circuits which would derive its non-arcing property from the nature of the material of the electrodes, as is the case with the non-arcing metal lightning arrester. Accordingly I directed my attention to the possible suppression of the dynamo arc by virtue of the construction or relation of the parts.

I had already observed the remarkable ease with which

disruptive discharges strike over insulating surfaces, as compared to the difficulty with which they ordinarily pierce the air. For example, disruptive discharges will strike over a glass surface, between two electrodes placed eight inches apart, rather than pierce the air between electrodes placed one inch apart and shunting the electrodes in contact with the glass. If ground glass be used and a pencil-mark be drawn between the widely separated electrodes, the ratio between the distances over the glass and through the air is increased. While endeavoring to avail myself of this principle of "surface discharge," as I have called it, it occurred to me that a dynamo arc, in order to exist, must be fed by the vapors of its electrodes, and that if such vapors could be suppressed, or if their formation could be avoided, an arc could not possibly exist. Placing these two ideas together, namely, "surface discharge" and "suppression of the vapors," I at once had the fundamental principles necessary for the construction of what has since proved to be a most simple and efficient non-arcing lightning arrester for direct current circuits.

In the first experiments which led to a practical adaptation of these ideas to the construction of a lightning arrester, I placed two aluminum-foil terminals between the surfaces of two small blocks of marble, the surfaces of which had been carefully ground, and on one of which I had drawn a pencil-mark which should bridge the distance between the foil electrodes. At first these electrodes were placed about two inches apart, the two blocks of marble were firmly bound together with twine, the terminals were connected to the terminals of a 500-volt direct current generator, and disruptive discharges were then caused to pass from one foil terminal to the other, between the marble blocks and over the pencil-mark. It will at once be seen that the function of one of these marble blocks was to furnish a surface discharge plane, that the pencil-mark was to further facilitate the passage of the disruptive discharge, and that the function of the second block, which was firmly bound to the first, was to suppress the formation of vapors, which would otherwise serve to establish a short-circuit under the condi-

tions of the test. No arc being formed, the terminal foils were brought successively nearer to each other, until finally, when the discharge plane had been shortened to one-quarter of an inch, a short circuit was established.

Without entering into the details of subsequent experi-

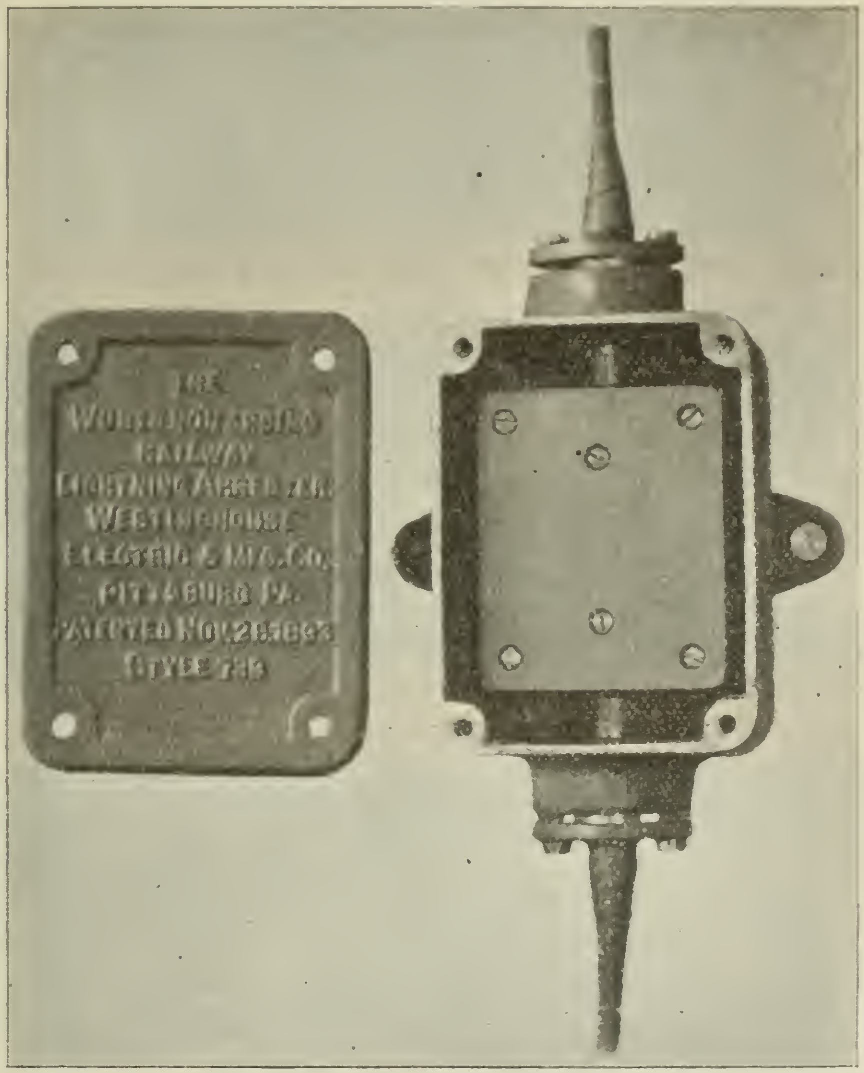


FIG. 7.—Non-arcing railway lightning arrester (for car or line use).

ments leading to the practical construction of a commercial lightning arrester, it may briefly be stated that the final form given to the arrester was that shown in *Fig. 7*. In this form wood, having been found more durable, has been substituted for marble, and, in place of the pencil-marks,

shallow grooves are burned longitudinally between the terminal electrodes, which are placed three-eighths of an inch apart. While submitting this form of lightning arrester to long-continued tests with disruptive discharges, it was found that there was a gradual wearing away of the wood fibre, which eventually ended in the formation of a cavity in which vapors formed in sufficient quantity to establish a dynamo short-circuit. The wearing away of the fibre seemed to be due to the fact that no special vent, or opportunity for displacement, was provided for the disruptive discharge. This evil was quickly cured by slotting the upper block at right angles to the charred grooves in such a manner as to open up the grooves or discharge plane to the air, without, however, uncovering the electrodes.

It will now be proper to notice the distinctive features of the two non-arcing lightning arresters which have been described. The non-arcing metal lightning arrester is non-arcing by virtue of the material of its electrodes, and though "non-arcing," nevertheless allows of the dynamo short-circuit. This is, however, so quickly interrupted, probably by virtue of non-conducting vapors which form between the electrodes during the first rush of current, that no appreciable burning or damage to the electrodes can be noticed, and the melting of fuses and consequent interruption to the service are entirely avoided. On the other hand, the non-arcing lightning arrester for direct current circuits is "non-arcing" by virtue of its construction; and, more than this, is, strictly speaking, a discriminating lightning arrester, in that it allows disruptive discharges to pass freely without allowing any dynamo current at all to follow. This last feature is one which has enabled me to make some interesting investigations regarding the relative volume of discharges from overhead wires during thunder-storms.

While carrying on a series of experiments in Colorado, during the summer of 1893, I connected in series with a number of these discriminating lightning arresters small spark-gaps, into which I inserted pieces of tissue paper, which were intended to act as telltales, and which, by the holes punctured by the discharges, gave me some record of

what was going on. Some of these tell-tale papers are shown in *Fig. 8.* It will thus be seen that, although

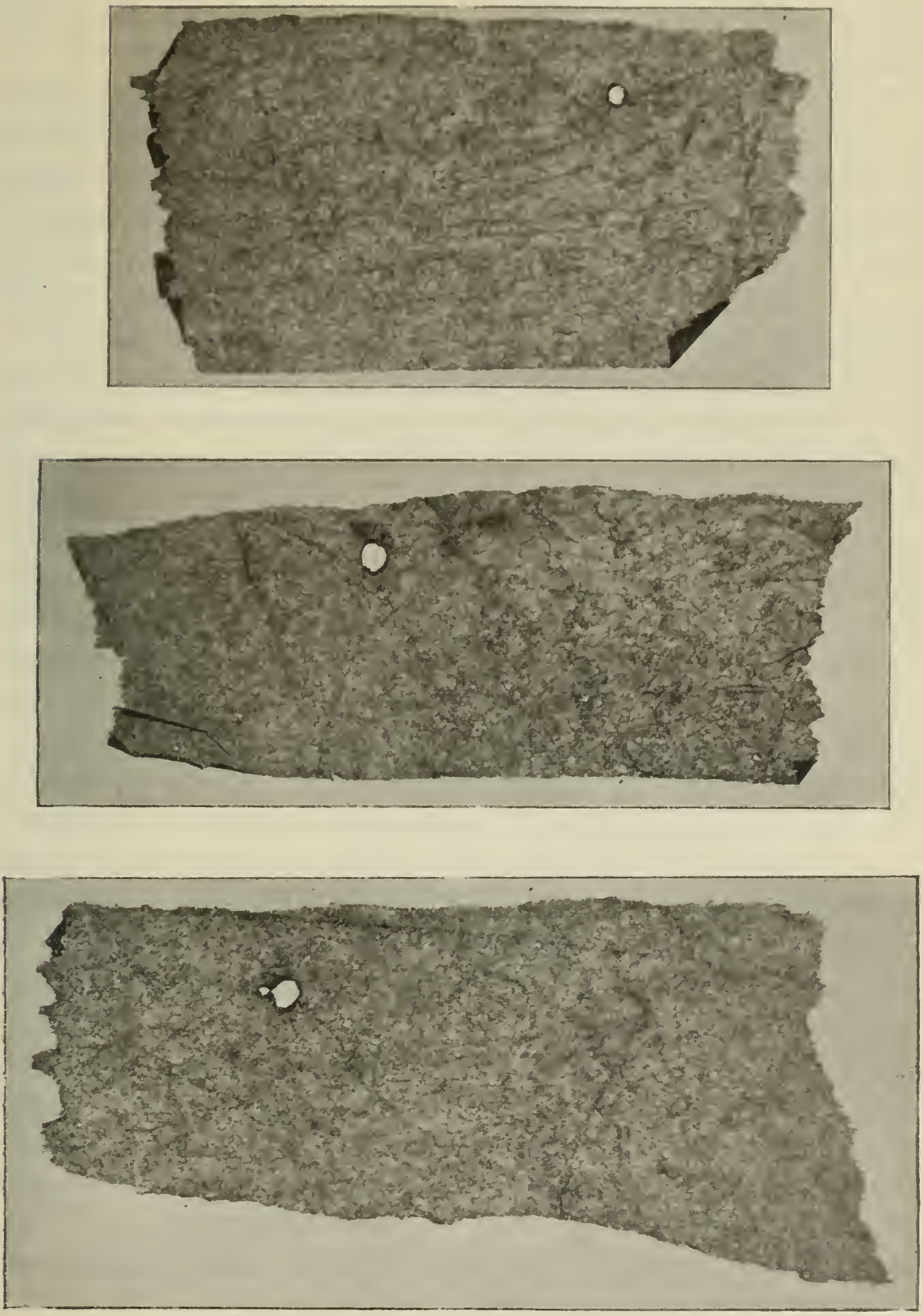


FIG. 8.—Tell-tale papers.

the discharges which caused these holes were larger than is ordinarily obtained with a battery of Leyden jars, they

are not to be compared with the holes which one would expect from the lightning flashes which are so often said to "strike the lines." The fact that these telltale papers were not burned is sufficient evidence that the dynamo current did not follow the discharge.

There is, however, another side to this matter of protection against lightning—one which has been little discussed, and which is almost invariably overlooked by those to whom interruptions due to lightning are a matter of vital importance. I refer to the insulation of the apparatus to be protected. When a lightning arrester "fails to protect" it is condemned, the general opinion being that the failure is due to some inherent fault in the lightning arrester. But we have already learned that a lightning arrester is nothing more than a spark-gap. It would be difficult, then, to conceive of anything fundamentally wrong with a lightning arrester, so far as offering an opportunity for discharge is concerned. We have also learned that disruptive discharges do not always embrace the opportunity for discharge which is offered by a spark-gap lightning arrester. This circumstance, a very frequently occurring one, explains why lightning arresters sometimes fail. Another and all too frequent cause is defective or improperly applied insulating material. In a certain sense a lightning arrester is a safety valve. One would not expect to protect a defective or weak boiler with a safety valve set to blow at or near the bursting strain of the boiler; no more should we expect a spark-gap lightning arrester to protect weak or defective insulation.

Defective insulation results either from weak insulating material, or a faulty *application* of the insulating material. Generally good insulating material is used. Faulty application may result in two ways: (A) Through improper design; (B) Through carelessness or ignorance. Examples under (A) are: (1) exposed surfaces offering opportunities for "surface discharge," and this is not an infrequent occurrence in connection with insulating materials which would otherwise stand very high voltages; and, (2) insufficient allowance for a proper margin of safety. The effects of rough handling, heat and cold, damp and dry atmos-

pheres, dirt and grit (this latter having a particular attraction for electrical apparatus, etc.), demand a margin of safety which is not always appreciated even by the designer. Under (B) might be mentioned a long list of details, such as bruises, cracks, pin holes, cuts, open joints, bits of metal imbedded in the insulation, sharp corners, etc., which will tend to lower the insulation strength fifty, seventy-five or even 100 per cent. And at this point it should be observed that the weakest point in the insulation of a given piece of apparatus (it may be a pin hole or minute crack invisible to the naked eye) is a measure of its insulation strength.

Repair work in shops of local electric light and power companies is liable to be more or less defective, and but few such companies are provided with testing sets. Re paired armatures and converters are placed in service and might stand indefinitely the normal E.M.F. of the circuit to which they are connected, but field discharges, lightning, rise of potential and proximity to other circuits carrying high potentials, demand a margin of safety which cannot be assured unless the insulation be actually tested with an E.M.F. from four to six times the normal.

But, even though the insulation of apparatus be perfect and have its proper margin of safety when installed, deterioration may, nevertheless, occur from various causes, principal among which would be moisture and overheating. In general, it may be stated that if we undertake, by means of spark-gaps, to provide absolute protection against static disruptive discharges, the insulation strength must bear such a relation to the spark-gaps as to place it beyond the limit of selection. Ordinarily, however, absolute conditions do not occur in practice, we can but approximate to them and then philosophically accept a reasonable percentage of failures as inevitable.

The failure of lightning arresters is too often due to careless installation. It may be instructive to note several examples :

(1) One plant is reported as having, for better protection, connected two arresters in series. This was probably done with the idea that if a little was good more would be better.

(2) A large bank of station arresters was grounded to an iron bolt about two feet long, driven into dry sand.

(3) Line arresters were grounded by pushing the ground wires into the earth.

(4) Line arresters were grounded on iron poles, which were themselves set in Portland cement.

(5) An annual inspection of automatic lightning arresters developed the fact that the arresters were nearly all burned out—in other words, that the line was left unprotected.

(6) The ground plate of a bank of arresters was thrown into a neighboring stream, which subsequently changed its course, leaving the ground plate high and dry.

(7) The ground plate of a bank of station arresters was laid on the rock bottom of a neighboring stream.

(8) In a large number of cases a portion of the ground wire is wound into a fancy coil (choke coil). And the list might be indefinitely extended, each such case forming a source of complaint that the arresters "fail to protect." But, when these curious mistakes are located and properly remedied the complaints cease.

Summary.—Overhead wires become charged. They are discharged through lightning arresters, which are spark-gaps. Shifting points of high and low pressure are formed along the line, so that the discharge does not necessarily occur over the shortest or easiest path; that is, the discharge is selective. Lightning arresters offer opportunities for discharge. Coils protect. A liberal distribution of line arresters offers the only practical means of protecting widely distributed apparatus.

Lightning arresters fail to "protect;" first, because of the shifting high- and low-pressure points, or in other words, for lack of a sufficient number of *line* arresters; second, because insulation is defective; and third, because lightning arresters are not properly installed.

SANITARY ENGINEERING.*

By Wm. Paul Gerhard, C.E., Consulting Engineer for Sanitary Works; Mem. Amer. Public Health Association; Amer. Forestry Association; German Samaritan Society; Corresp. Mem. Amer. Inst. of Architects; Honorary Consulting Sanitary Engineer to the Department of Health of the City of Brooklyn, N. Y., etc.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

The subject upon which it is my privilege to address you to-night was, up to within a few years, comparatively unknown. Sanitary engineering—like electrical engineering—is one of the recent branches of civil engineering; sanitary science, the researches of which form one of its foundations, may likewise be considered a new science, although it has, in the last few years, made such rapid strides that its importance is beginning to be more universally recognized.

The general public has but a vague idea of the meaning of the term "sanitary engineering." Many mistaken or narrow views exist in regard thereto, which, I trust, my remarks to-night may help to dispel. Having lived for many years in each of the three continents of Europe, Africa and America, and being, therefore, somewhat of a cosmopolitan, I trust you will overlook the fact that some of the statements which I shall make do not refer exclusively to American conditions.

ARCHITECTURE AND ENGINEERING.

As soon as a science, art or profession expands to such an extent, both in theory and in practice, that its entire field can no longer be mastered by one mind, it divides itself naturally into departments or specialties. We know this has been the case in law, in medicine, in the fine arts, and in the natural sciences. In fact, ours is the age of specialists in all branches of learning, in all arts and

*A lecture delivered before the Franklin Institute of Philadelphia, Pa., February 15, 1895.

sciences. Such a sub-division has also gradually taken place in the profession or art of engineering: thus it came about that sanitary engineering was made a special and distinct branch of the profession of civil engineering.

Let us glance briefly at the origin, and define the meaning, of this new branch.

Centuries ago the whole science and art of building construction were concentrated in one profession. At that time there existed even no division into engineers and architects. Architecture and engineering were not only combined, but merged together with other professions or arts. In those by-gone times a man could be, at the same time, a painter, a sculptor, an engraver, a designer and builder of church edifices, a constructor of fortifications, an engineer of canals. The thought of a Michael Angelo Buonarotti, of a Leonardo da Vinci, of an Albrecht Dürer, will readily recur to you. To-day, however, all this has been changed. The complex requirements of modern civilization, the multiplication of human wants—not to mention the exigencies of business competition—render it well-nigh impossible for such universal genius or master-mind to rise to success. While there may occasionally be exceptional instances of accomplished men who are proficient in many things, as a general rule those will succeed best who limit themselves to the study and practice of one specialty.*

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*After writing down the above, I happened, for the first time, to come across a passage in the poem "Lucile," by Owen Meredith, which expresses exactly the same views. It is as follows:

"The age is gone o'er
When a man may in all things be all. We have more
Painters, poets, musicians and artists, no doubt,
Than the great Cinquecento gave birth to; but out
Of a million of mere dilettanti, when, when
Will a new *Leonardo* arise on our ken?
He is gone with the age that begat him. Our own
Is too vast, and too complex, for one man alone
To embody its purpose, and hold it shut close
In the palm of his hands. There were giants in those
Irreclaimable days, but in these days of ours—
In dividing the work, we distribute the powers."

Lucile, Part I, Canto 1, III.

It is now a little over a century ago that in building construction the first division into the two independent professions of architecture and engineering took place.

Broadly speaking, architecture deals with the ornamental, whereas engineering embraces the purely utilitarian branches of construction. It should be said, however, that while, from a purely business aspect, in the practice of the art, this division exists, the line cannot be quite so strictly drawn as regards the preparation and training required for the subsequent practice of the professions. It lies in the nature of their work that architects must be, to some extent, engineers; they must understand construction in order to be able to design, whereas the reverse of this proposition is not quite so evident, for to find artistic talent and skill in an engineer is rare. To some extent, nevertheless, these two professions have always remained in close touch, and in recent years architects and engineers have once more been drawn together, particularly in such works as pertain to landscape and to domestic engineering.

DEFINITION OF CIVIL ENGINEERING.

The profession of civil engineering has been defined as "the art of directing the great sources of power in nature for the use and convenience of man." The organization of the first State engineer corps occurred in France, in 1791, when the Corps des Ingenieurs des Ponts et des Chaussées was established. As the name implies, the work of these *civil* engineers consisted largely in the development of means for better transportation for passengers, as well as goods, such as the construction of roads, bridges and canals; whereas the *military* engineers constructed works of fortification, and applied engineering construction to military operations. Soon after, followed the construction, equipment and management of railways and the improvement of rivers, harbors and other aids to navigation. Other branches were added from time to time, such as the manufacture and improvement of machinery and mechanical appliances; the operating of mines; the establishment of telegraph and telephone lines; the erection of gas works; the application

of electricity for producing light, heat and power; the fire protection of buildings; the water supply, sewerage and lighting of cities; the drainage, lighting, heating and ventilation of buildings; the reclamation of marshes and agricultural drainage; the laying-out of streets and towns, squares and parks; the construction of piers, docks, sea-dykes, jetties, breakwaters and lighthouses. Broadly speaking, engineers deal both with structures and with machines, the former being, according to Rankine, combinations of materials, the parts of which have no relative motion; and the latter, mechanical appliances whose function is to perform useful work, and the parts of which move.

ENGINEERING SPECIALTIES.

At the present day we may distinguish the following divisions of engineering, viz.:

Military Engineering,	Electrical Engineering,
Railroad Engineering,	Gas Engineering,
Hydraulic Engineering,	Municipal Engineering,
Marine or Naval Engineering,	Sanitary Engineering,
Bridge Engineering,	Landscape Engineering,
Mechanical and Steam Engineering,	Fire Protection Engineering,
Mining Engineering,	Architectural Engineering.

As previously stated, it is impossible for one man to acquire a complete knowledge and practice of all branches, and the tendency to specialization leads engineers to devote themselves to some one particular field. Notwithstanding this division into separate branches, made necessary largely by business considerations, the various branches often meet. Much of the work of the municipal or city engineer, for example, refers to sanitary, to hydraulic, and to gas engineering; the landscape engineer and the architect meet in the laying out of country estates, city gardens and public parks; the sanitary and the mechanical engineer meet in the planning and construction of heating and ventilating plants; the sanitary and the hydraulic engineer, in works of water supply or sewerage for cities, villages and institutions; the architect and the sanitary engineer, in all that pertains to healthfulness of habitations; the architect and the bridge engineer in the iron or steel construction, and

the foundations of large and tall buildings. These examples might be multiplied, but what is said will suffice to explain my meaning.

DEFINITION OF SANITARY ENGINEERING.

If we accept the above definition of civil engineering, then sanitary engineering may be defined as the art and science of applying the forces of nature in the planning and construction of works pertaining to public or individual health; or, to put it in other words, the purpose of all works of sanitary engineering is the promotion of healthful conditions, the avoidance of disease caused by outside influences, which may be brought under control of mankind, and the increase of the duration of life. *It is obvious, therefore, that a general knowledge of civil engineering, of architecture and of sanitary science, in all their branches, should form the basis of the education of the sanitary engineer.*

Some persons among my audience may contemplate taking up the profession of sanitary engineering, or there may be fathers present here to-night who desire to have their sons follow a course of studies which would prepare them for this branch. I will, therefore, even at the risk of wearying you, make an attempt to outline briefly the course of studies and the special training required to enable one to attain the qualifications necessary to practice sanitary engineering. Following this, I shall describe and discuss the principal subjects or problems with which the sanitary engineer deals in his practice. In order to become a competent engineer, the course of study should embrace both theoretical (scientific and technical) education and practical or manual training. The practical education differs according to whether the special branch, which the engineer will follow later on, belongs to mechanical, civil, electrical or sanitary and hydraulic engineering.

COURSE OF STUDY IN SANITARY ENGINEERING.

In order to be able to make use of the forces of nature for the promotion of the comfort, health and welfare of mankind, it is necessary to study and to become conversant

with them; hence, training in the natural sciences and in mathematics forms the basis of sanitary as well as of all other branches of engineering. The study should include mathematics (arithmetic, algebra, geometry, trigonometry and stereometry), astronomy and descriptive geometry; likewise, of the physical sciences, mechanics and dynamics, hydrostatics and hydraulics, aërostatics and aërodynamics; the theory of heat, optics, acoustics, magnetism and electricity. It is also necessary for the engineer to have some knowledge of meteorology, climatology, physical geography, mineralogy and geology; furthermore, of general chemistry, metallurgy, and, in particular, of chemical technology. The study of botany, of the trees of commerce and of forestry is also useful in many ways. In none of these studies, however, must the young engineer student expect to become complete master; even in mathematics, which is to the engineer the basis of all learning, he cannot expect to cover the whole field.

He must become acquainted with the properties of the materials employed in engineering structures, and gain a knowledge of the principles of construction, of the theory of strength of materials, and of the stability of structures. Without this knowledge, he cannot attain eminence in his profession.

All engineers should be good draughtsmen; therefore, the student should practise not only general drawing and sketching, but become skilful in particular in mechanical drawing, in the preparation of engineering drawings, and, to a certain extent, of architectural plans, sections and details. He should also learn geodesy, surveying, levelling, the laying out and staking out of work, and should aim to thoroughly master topographical and map drawing. All these studies are fully as useful to the sanitary engineer in his practice as they are essential to the civil engineer.

The studies mentioned so far comprise the general or preparatory course in engineering. After this should follow special courses in engineering as related to commerce, which comprises the means of transportation and communication on land and on water; in engineering as related to

agriculture; in engineering as related to manufacturing industries and mining; in engineering as related to buildings, and, finally, in engineering as related to public health. He should learn road and street construction, railroad and tramway building, hydraulic engineering, sewerage, water supply, measurement of water power, bridge, roof and tunnel construction, works of drainage and irrigation, canals and locks, river improvements, harbor and sea-coast works, machine construction, and the application of the different classes of motors. A general course in architecture or building construction is also desirable for the well-qualified sanitary engineer, and this should include some knowledge of the trades of carpentry, bricklaying and stone masonry, plastering, blacksmith work, plumbing, gas-fitting and drain-laying.

In addition to these, there should be a course in sanitary science, comprising public and personal health, and a study of the causes and methods of preventing the spread of infectious and contagious diseases. A fundamental knowledge of anatomy and physiology, so useful to men in all conditions of life, is of paramount value to the sanitary engineer, and this should be followed by a special course in "First Aid to the Injured," as now made a feature in all German polytechnic schools. This will prove eminently useful in the subsequent practice of the engineer, in case of accidents or emergencies, whether in the machine shop, on buildings, in railroad disasters, or in sanitary and hydraulic works.

Finally, the general knowledge of language and grammar should not be overlooked, as engineers are frequently called upon to write reports. The study of foreign languages will prove useful in travelling and in many other ways. And, finally, there should be added a general knowledge of law, so necessary when drawing up contracts or preparing specifications, the cultivation of business habits, and the faculty of dealing with foremen and workmen in the superintendence of works.

You will see from all this that the extent of theoretical knowledge and practical acquirements which the sanitary

engineer should possess is quite formidable. It has been truly said that "no man in an ordinary lifetime can properly learn engineering," and that "the learning period of an engineer ends only with his death."

Although it follows clearly from what has been said that the foundation for the special study of sanitary engineering, should be a regular course in civil engineering, it by no means follows that every civil engineer is also a well-qualified sanitary engineer. In order to become competent for the duties of a sanitary engineer, the civil engineer should—in study as well as in practice—give special attention to, and gain knowledge and experience of, all those problems which are correlated to, and which influence, public health. Sanitary engineering covers a very wide field, and is a profession requiring years of preparation and hard work.

ACTUAL PRACTICE OF THE SANITARY ENGINEER.

I will now attempt to give you in outline a very general review of the various classes of work and of the problems arising in the professional practice of the sanitary engineer. I would overstep the limits of this paper were I to discuss any of those questions or topics in detail. I can mention many subjects only casually, and my difficulty is the constant embarrassment of deciding what to omit rather than what to mention.

Speaking generally, much of the work performed by the salaried city or municipal engineers is sanitary engineering. If the sanitary engineer has a private practice, he will often be called upon to act as consulting or advisory engineer for municipal works; or his work will be more in the nature of private architectural engineering and domestic work, such as heating and ventilating of buildings, plumbing and drainage, water supply, sewerage and sewage disposal.

WATER SUPPLY OF CITIES AND OF DWELLINGS.

One problem which belongs to sanitary, and likewise to hydraulic engineering, is the provision of a bountiful supply of pure and wholesome water for cities and towns. A pro-

ject for water works requires investigations as to the quantity needed; as to the quality and available sources of supply; as to the pressure required and the division into pressure districts; as to the means for conducting the water from its source to the places of consumption and the systems of pipe distribution; as to the methods of storing the water, protection against contamination, and, finally, as to the means of purification.

Water is required for many uses, such as for drinking, cooking, washing, bathing and general ablutions: for cleaning; for sprinkling sidewalks and streets, areas and yards and watering gardens; for fire-extinguishing purposes; for flushing water-closets, drains and sewers; for washing carriages and watering horses and cattle; for feeding steam-boilers, supplying fountains, running hydraulic elevators; for industrial establishments, laundries, dyeing establishments, paper factories, breweries and sugar refineries, etc.

From a sanitary point of view, the chief considerations are the sources of supply, quantity, quality, pressure, storage, the material of distributing pipes and the artificial improvement of the water.

The sources for a water supply are rivers and lakes, springs and gathering ponds, which are naturally good, but liable to be polluted by surface washings or by sewage; rain water, which is pure in the country, but contaminated in cities; sub-soil and ground-water, which, away from habitations, is good; shallow wells which are always open to suspicion; and deep artesian or driven wells, which, as a rule, furnish an uncontaminated water supply, but which is not in every instance available for use. A sanitary examination of the source of supply should always be instituted, and comprises a chemical, microscopical and bacteriological analysis of the samples, in the gathering of which particular care is required.

The quantity of water required should be determined according to the rate of growth of population, and according to the special needs of water for domestic and personal, for industrial and for public use. The amount of water required per head per diem will naturally fluctuate with the

customs, desire for cleanliness, and the social conditions of the inhabitants of a place, likewise with the extent of manufacturing industries, the number of public baths, public institutions and public fountains, and, finally, according to the mode of supply, *i. e.*, whether this is unlimited or metered. The consumption also varies at different hours of the day, on different days of the week, and in different seasons of the year, and this should be borne in mind in the design of a water works system.

The quality of the water is another consideration of importance. The fact needs to be emphasized, that clear water is not necessarily wholesome water; and inversely; water may be good without being absolutely pure from the chemist's point of view. Good water, suitable as a beverage, should be transparent, colorless, odorless, tasteless, moderately hard and cold and free from organic impurities and disease germs.

The pressure at which water is supplied is of interest mainly from the point of view of fire protection, but also as regards the supply in dwellings, for a deficient pressure points to the need of storage cisterns in houses, and in some places necessitates the use of domestic pumps to lift the water to the tanks.

Deficiencies in quality, quantity or pressure of the water supply may be the cause of disastrous calamities to life as well as property. To guard against these, stand-pipes or storage reservoirs often form a part of the distribution system. In the reservoirs, the water stored is frequently subject to vegetable growths or algæ, which impart to it a bad taste or odor, or both.

The method of supply is either constant or intermittent; the former is far preferable for sanitary reasons, and may be either a free and unlimited supply, or the supply may be controlled by water meters. The system of supplying consumers by meter measurement prevents unnecessary waste of water, due to leaky house-fittings or carelessness and negligence in use, and is not, from a sanitary point of view, objectionable, as many suppose.

The supply of water to a city may either be brought to

it by open or covered gravity conduits, or it must be pumped, by hydraulic or steam-power, into reservoirs or into pressure conduits. The distribution in the city streets is usually by a network of underground iron pipes, and the domestic water service is effected by smaller distributing pipes, the material of which may have a bad influence on the quality of the supply.

Finally, the artificial improvement of the supply is a problem which concerns the sanitary engineer. It may be accomplished on a large scale, either by sedimentation, by sand filtration on filter-beds, by distillation, by aëration, or by chemical precipitation processes, requiring the addition of substances like alum, lime, or perchloride of iron. In the home, small domestic filters may effect some purification, but nearly all the household filters merely strain the water without actually purifying it, and, unless they are frequently and regularly cleaned and recharged with fresh filtering material, become worse than useless. There are a few household filters which do remove the germs from the water; but all those which have any merit necessarily filter the water very slowly and require occasional cleaning and sterilizing.

Incidental to the use of water as a beverage is the employment of water in its solid form as ice, for the purpose of rendering the temperature of the water more agreeable. It is a popular fallacy that ice is water purified by freezing. Recent progress made in bacteriology has established the fact that germs of disease, such as typhoid germs in drinking water, are not killed by the process of freezing. Danger, therefore, lurks in the indiscriminate use of ice. The business of ice-cutting requires careful watching, and should be under the control of sanitary engineers of Boards of Health. The cutting of ice from ponds or rivers subject to organic contamination, and rendered unfit as a source of ice supply, should be prohibited. Careful householders should, for like reasons, as a matter of precaution, make use of water coolers so arranged that the ice is kept in a separate compartment, so that in melting it cannot mix with the drinking water, or they should order their ice supply only from dealers in artificial ice, manufactured from distilled water.

SEWERAGE.

The water supplied to a city from its water works must be removed after use. To accomplish this is one, though not the only, object of a sewer system. Town sewerage, in the wider meaning of the term, signifies the removal, by underground conduits or sewers, of the sewage of a city, which may include a portion or all of the following liquid wastes: house waste, including excreta and urine; stable wastes, manufacturing wastes from industries using in their processes large volumes of water; waste from water motors and hydraulic lifts; subsoil water; and, finally, surface or storm water, falling on roofs, yards, areas, courts, paved streets and unpaved spaces. From a sanitary point of view, the continuous and instant removal, before putrefaction begins, of all liquid waste products from habitations, must be the chief consideration in order to avoid the pollution of soil and air in and about dwellings, and the contamination of the ground water. To be able to devise a sewerage system, it is necessary to institute many preliminary investigations, which refer to the present and future extent of the drainage area, the configuration or topography of the city, the geology and physical character of the drainage district, the meteorological observations, particularly as to the rainfall of the place, including the frequency and amount of sudden heavy showers; the proportion of rainfall, if any, which is to be admitted into the sewers; the character and quantity of the daily and hourly water supply; the size of population, present as well as prospective, which will derive practical benefit from the sewers, and the comparative density of population in different sections of the city.

Another question of prime importance in the establishment of a sewerage plan, is the final disposal of the sewage; the location of the sewer outfalls; the nature, volume of flow and velocity of current of the water course intended to receive the sewage, the requirements of pumping stations, or the need of sewage purification works. It may be laid down as an axiom that no engineer can give intelligent advice concerning a proposed sewerage system of a city, without having a correct general contour map of the place.

Following these preliminary investigations the sanitary engineer should consider the various sewer systems, the combined and the separate system, the gravity, suction and compressed air systems of sewage removal, and decide which is best adapted to the locality in question. Often it may be advantageous to admit into the sewers only a portion of the liquid wastes enumerated. In many towns storm water may be left out of consideration, as, for instance, where it can be taken care of quite sufficiently by open or covered street gutters, or by a few shallow and short rain-water sewers, discharging in a straight line into the nearest water course. Wherever sewage must be pumped to the outfall, and in all cases where it must be purified before discharge into a water course, the advantages of the separate system predominate.

After deciding upon the system of sewerage best adapted to the needs of a community, a general sewerage plan should be developed, and according to the topography of the city, various lay-outs for the division into sewer districts may be followed, such as the direct or perpendicular system, the intercepting system, the zone or parallel system, the fan system and the radial system, the details of which I cannot describe here. The grade and inclination of the sewers, the resulting velocity of flow, the importance of making sewers self-cleansing, the depth at which they are laid below the street level, the sectional forms and sizes, the material and construction, whether cement or vitrified pipe or iron pipe sewers, concrete, brick or stone-masonry sewers, these are all matters of importance, which the experienced sanitary engineer has to consider. In the construction of the sewers many questions of detail come up, upon which the ultimate success of the system will depend, such as the trenching, the provision of proper foundations in loose soils, the use of invert blocks, the making of water-tight joints in pipe sewers, the proper junction of sewers, the careful alignment and the adjustment of the grade, the smoothness, hardness and durability of sewer pipes and other considerations. Sound, practical judgment will determine the position and number of man-holes and lamp-holes for purposes

of inspection, location and removal of obstructions, the advisability of using devices for flushing sewers, either flushing man-holes, gates or tanks with automatic siphons, and the detail of sewer outfalls. Where rainfall is admitted to the sewers, the construction of catch-basins at street corners and of storm overflows to relieve the sewers in case of sudden heavy showers must be studied. Where sewage cannot be discharged by gravity, pumping stations and sewage pumps must be designed; finally, the house connections must be provided, in wet soils subsoil drains must be laid in the sewer trenches, and in all cases the sewers must be well ventilated.

The problem of sewer ventilation presents many practical difficulties. The prevailing method, by means of perforated man-hole covers, is open to objections, particularly in narrow streets or courts, and the alternative of untrapped catch-basins aggravates the evil, owing to the proximity of the latter to the windows of dwelling houses. Among the various other methods suggested from time to time, I mention ventilation by means of the rain-water pipes of buildings, which is objectionable, first, because during rainstorms, just when sewers require a free vent, owing to the displacement of the air by water, the rain-water conductors cannot act as ventilators; second, because the joints of outside metal leaders are rarely tight; and third, because rainwater leaders often terminate under windows of living rooms or sleeping apartments. Ventilation by lamp-posts or special columns rarely accomplishes much, because they are of too small diameter. The carrying of special sewer vent pipes along the outside of buildings would be somewhat more effectual, but the method is difficult to enforce, expensive, and often troublesome in case of adjoining buildings of various heights. Ventilation of sewers by connection with chimney shafts or boiler flues involves the possibility of explosion, or is objected to by the owners, as it may injuriously affect the chimney draft. Special tall shafts, at the upper ends of sewer lines, are, to some degree, effective, but very expensive. Other propositions include charcoal ventilators in the top of man-holes, which require frequent

removal, material placed in sewers to absorb gases, and the passing of disinfecting vapors or chemical gases into the sewers. Unfortunately, most of these devices suggested are costly or difficult to apply, and the problem is by no means satisfactorily solved. One other method deserves special mention, it being a successful feature of the separate system; this is the omission of the running trap on all house drains, thus making use of the house soil and vent pipes, which are carried up to the roof. With a well-flushed, well-arranged and well-maintained sewer system, under complete control of the municipal engineer, the simple method is perfectly feasible, and gives good results, provided the drainage works of the houses are absolutely air-tight.

A public water supply and a sewer system are improvements which usually go together, and exercise a marked sanitary effect upon the general health of a community. The problem becomes more difficult when there is a water supply without sewerage, in which case the filthy and health-destroying cesspool, or the vault, is the usual receptacle of the sewage pending removal by cartage. Where there is neither sewer nor a water supply, the disposal of filth must be accomplished by dry removal systems, such as the earth or ash closets, or the pail system. Finally, there are certain special systems, such as the pneumatic systems of Liernur and of Berlier, and the mode of pumping sewage by compressed air by the Shone system, of which a practical application could be seen at the recent World's Fair in Chicago, with all of which the sanitary engineer should be quite familiar. Of all systems, that one will be by far the best, from a hygienic point of view, which effects cleanliness by a constant, systematic and quick removal of all manner of liquid organic rèfuse from houses, streets and towns.

PREVENTION OF POLLUTION OF WATER COURSES.

Rivers and water courses have been utilized as the natural outfalls for the sewage of towns. As the amount of town sewage increases, owing to growth of population, and of its industrial establishments, the streams and water

courses become more and more polluted, to the great detriment of the people living further down stream. River pollution, in numerous instances, has been the result of improved town sanitation by sewerage. Too much reliance has often been placed in the assumed self-purification of rivers. In many instances, furthermore, clear streams flowing through the heart of a city, have been made the receptacle of all its liquid wastes, with the result of turning a once pure water course into an extremely foul open sewer, contaminating the air of the town. This offensive practice cannot be too strongly condemned from a sanitary point of view. The experienced sanitary engineer will uphold the axiom that in cities all natural water courses must be kept unpolluted. Even the smallest open streams should, under no circumstances, be covered or arched over and used as sewers. Filth should be prevented from reaching these open streams, and they should be kept pure with plenty of water and by a free circulation of air, and may, by proper rectification, be used to serve as a natural embellishment of a city.

Regarding larger water courses flowing past a city, the question whether or not sewers may discharge directly into them depends upon a number of factors which must be carefully considered by the engineer. A certain amount of self-purification is, no doubt, always going on, due largely to the sedimentation or subsidence, to oxidation and aëration and to dilution; and with this in view there is a certain degree of permissible pollution. Speaking generally, the larger the volume of the water course, and the greater its velocity of current, the more sewage can be admitted to it without danger of undue pollution. The condition of the water course before it reaches the town should also be considered, but the chief question will always be whether the water of the river is, or may in the future be, used at a point below the sewer outfall as a source of potable water. In that case the direct discharge of unpurified sewage should never be permitted, for the preservation of the purity of water used for public water supply is of paramount importance. We may even go a step further and demand a certain amount of purification of sewage, before discharge into

rivers or lakes, in order to keep these inoffensive even where they are not drawn upon to supply the drinking water, making the required degree of purification variable according to the circumstances of each case. Small lakes, stagnant ponds, coves, bays or inlets should never be used as receptacles for town sewage. In manufacturing districts difficulty often arises from chemical wastes, and from the fact that the volume of water of the stream is considerably reduced on account of the flumes which divert part of the water to use it as motive power. On the other hand, artificial dams, like rapids and natural waterfalls, aid the purification by aëration and oxidation.

SEWAGE DISPOSAL.

The question of the proper disposal of the sewage of populous places is one of the most important, and often difficult, problems which the sanitary or municipal engineer encounters. In many sewered cities of Europe, particularly in the case of inland towns, sewage purification systems have long ago been devised and adopted, while in the United States the difficulty is only beginning to be appreciably felt with the increasing pollution of our rivers. A direct discharge of sewage into a water course or into lakes and tidal rivers is seldom permissible. Even the casting away of crude sewage into the sea can only be countenanced under special conditions, as it quite often leads to a defilement of the beaches, and tends to create mud-bars and silts up the navigable channels at the entrance of harbors. Frequently the argument is used against this method of disposal, that it is a waste of fertilizing materials. It should be said, however, that none of the methods of sewage disposal can be carried out with a view to financial gain. The purification of the sewage is, in all cases, the chief object.

The methods of purifying sewage may be divided into natural and artificial methods. To the former belong the simple sedimentation or subsidence, filtration through soil and broad surface irrigation. Among artificial methods, I mention the simple straining of sewage, mechanical filtration, chemical precipitation, aëration processes, and the

purification by electrical currents. Quite often a combination of two of these methods is adopted, and it is impossible to say, in a general way, which is the method that will yield the best success. The sanitary engineer must study each problem separately and use sound judgment in selecting a method best adapted to the existing conditions. Certain scientific experiments, however, and the actual experience gained in cities having various processes in operation will serve as a useful guide.

Simple sedimentation or subsidence is a slow method which rarely effects more than a mere clarification of the sewage, and removes none of the matters in solution. This is also true of the cruder methods of straining or filtering sewage in mechanical filters, and these processes may be considered rather useful as preliminary methods to be followed by broad irrigation or intermittent downward filtration. Chemical precipitation consists in the addition of certain chemicals, such as lime, or sulphate of alumina, or salts of iron, which act as precipitants, causing the suspended matters and a part of the dissolved impurities to be removed. The precipitation takes place in large sewage tanks, and is effected in a variety of ways. In some the sewage comes to a complete rest for several hours, and this method requires, therefore, a large number of tanks. Or the sewage, after the addition of the chemicals, is made to move slowly through shallow tanks, or it is compelled to follow up and down movements in the same. Finally, instead of large shallow tanks, deep upright tanks, cylinders or wells, placed either above or below the ground, are used in certain chemical precipitation processes. None of the numerous chemical processes effect a complete removal of all foul matters, and where the effluent is required to be very pure, the chemical method is often supplemented by irrigation over, or filtration through, soil. In all precipitation processes a new difficulty arises on account of the unavoidable accumulation of sewage sludge, which contains a large percentage of water. This sludge must be dried, either by spreading it out on well-underdrained land, or by pressing it in filter presses. The sludge cakes have some value as

manure, but a financial return from their sale is seldom realized. In some cities, the solid house and street refuse is mixed with the sludge and burned in garbage-cremating furnaces.

In the natural method of sewage disposal, sewage is made to flow either over or through land prepared for the purpose, and an excellent degree of purification is usually attained. Sewage irrigation over cultivated land is assisted during part of the year by the vegetation, the cultivation of certain crops on the sewage disposal field being perfectly feasible. The difficult feature of the system is the need of large areas of well-drained land. Near cities these are not always available, or when they are to be found they require a large outlay of money. Irrigation and filtration through soil also involve the constant need of manual labor.

Aëration processes are seldom adopted, although the oxidation of the organic matters in sewage, either by forcing air through it, or by causing it to run over a series of terraces or waterfalls, or by dripping it down on wire meshes, appears to be practicable.

The treatment of sewage by electricity was introduced experimentally in England several years ago; more recently it has been tried in the United States on a small scale, but sufficient practical experience is not yet available to permit definite conclusions to be formed as to the results to be attained by the process.

[*To be concluded.*]

NOTES AND COMMENTS.*

THE REGULAR SPEED OF OCEAN LINERS.

The following interesting facts are gleaned from the *Scientific American:*

The records of the Foreign Mail Bureau of the Post Office Department show that, as an ordinary thing, the ocean packets are almost as regular in their departures and arrivals as railroad trains, and, considering the distance they travel, even more so. The science of navigation has been reduced to such accuracy that they may be expected almost upon the hour. Take, for example, the *Campania*, of the Cunard Line. In 1893 she made eight trips,

* From the Secretary's monthly reports.

and her average voyage was 5 days, 20 hours and 18 minutes. In 1894 she made ten trips, and her average was 5 days, 20 hours and 17 minutes; only one minute less in 1894 than in 1893 in a voyage of 2,770 miles in all sorts of wind and weather. Nor is this exceptional. The *Teutonic*, of the White Star Line, made twelve trips in 1893, on an average time of 6 days, 4 hours and 8 minutes. In 1894 she made eleven trips, and her average was just a trifle slower—6 days, 4 hours and 17 minutes. The *Etruria* is a little more irregular. Her average in 1893 was 6 days, 6 hours and 47 minutes. In 1894 it was 6 days, 7 hours and 28 minutes.

The *Havel*, of the North German Lloyd Company, made ten trips in 1893, with an average of 7 days, 7 hours and 38 minutes for a distance of 3 080 miles, from the Needles to Fire Island. In 1894 she made nine trips, with an average of 7 days, 7 hours and 24 minutes. The *Fürst Bismarck*, of the Hamburg Line, made nine trips in 1893. Her average for the year for a voyage of 3,080 miles, was 7 days and 15 minutes. In 1894 she made six trips, and her average was 7 days and 54 minutes. The *Columbia* made nine trips in 1893, with an average time of 6 days, 22 hours and 12 minutes. In 1894 she made six trips, with an average of 6 days, 22 hours and 8 minutes.

The *New York*, of the American Line, though not the fastest, has the best record for regularity of any of the Atlantic fleet. Her average time has not varied for years, and she can be expected almost on the minute every voyage. She has crossed the Atlantic more times and has carried more passengers than any other steamer of her age, and has been more regular about it. The *New York* made fourteen trips, west bound, in 1893, with an average time of 6 days, 21 hours and 31 minutes. In 1894 she made fifteen trips, west bound, with an average of 6 days, 21 hours and 45 minutes. Her sailing distance was 2,770 miles. In 1893 she made thirteen trips, east bound. with an average of 6 days, 20 hours and 30 minutes, which was just one minute faster than her west bound time that year. In 1894 she made fifteen trips, with an average time of 6 days, 20 hours and 24 minutes. Therefore, in crossing the ocean fifty-seven times in both directions, at all seasons of the year, her widest variation for two years was only 1 hour and 21 minutes. The old *City of Chester*, also of the American Line, is another steady boat, her average being 9 days, 15 hours and 11 minutes in 1893 and 9 days, 15 hours and 28 minutes in 1894.

Electrolytic Production of Caustic Soda and Chlorine from Common Salt.—Extensive works, says *Le Genie Civil*, have recently been established at Oldbury, near Birmingham, England, for the electrolytic preparation of chlorine and caustic soda from salt.

The elementary apparatus is a pan about 6 feet in length, 3 in width, and 6 inches in depth, divided into three longitudinal compartments by partitions which do not touch the bottom. To these receptacles there is given a continuous slight horizontal motion in order to cause the circulation of a layer of mercury which covers the bottom. In the lateral compartments there is a

saturated solution of common salt, which is continuously renewed, and into which enter anodes of compressed carbon. A lead cover closes the compartments and communicates, by means of piping, with a collector, which leads the chlorine to the places where it is to be used.

The central compartment is provided with iron cathodes, and in it there circulates a continuous current of water, which carries the caustic soda to a concentration of about 20°.

The electrolytic pans having been connected in series, there is sent into them a current of 550 ampères, at four volts to each pan. Under the action of this current, the chloride of sodium is decomposed. The chlorine, mingled with traces of hydrogen (from three to five per cent., on an average), is sucked up by aspirators, while the sodium dissolves in the mercury, forming a cathode. The amalgam of sodium is decomposed, in turn, in the central compartment; the sodium reacts upon the water and becomes converted into caustic soda, and this action produces a strong electric current which reinforces the general current. Up to the present no effort has been made to collect the hydrogen.

The solution of caustic soda is kept at a density of about twenty per cent., and in this state is sent to evaporators, where it is concentrated into blocks that contain 99·5 per cent. of pure caustic soda.

The establishment contains thirty pans, which permit of the daily production of 1,300 pounds of caustic soda and 1,100 of liquid chlorine.

THE COST OF POWER AT NIAGARA.

The representatives of many established industries, and of not a few new enterprises, throughout the country, are anxiously awaiting the starting into operation of the great electric power transmission plant at Niagara, to learn from the experience of that important enterprise what may be expected to be realized from the utilization of water-powers elsewhere. The success of the Niagara plant will signalize the beginning of a large number of enterprises, more or less ambitious, of the same nature, throughout the country.

The following article, from a recent impression of the *New York Tribune*, contains some information bearing on the subject, which will be read with interest:

The company which has undertaken to develop electricity, at Niagara, on a large scale, for manufacturing and other purposes, has acquired more real estate there than it needs for its own use, in order to furnish sites to such of its customers as wish to establish their business close to the source of their mechanical power supply. But the public has been led to expect that in addition to serving local interests, the company would also furnish electricity to places scores, if not hundreds, of miles away, and there has been much speculation as to the feasibility of carrying such plans into effect. Owing to her proximity to the Falls and her great size and industrial activity, Buffalo has been regarded as the first center of population, removed from Niagara, to be provided for. It is not yet quite clear whether that city feels that it is

enjoying a privilege or conferring a favor in letting the Power Company invade its precincts. Perhaps she has not determined that point herself. The matter is evidently still under consideration. In reply to some inquiries from representative Buffalonians, the Power Company recently offered the following terms: It would let the municipality or a private corporation come to Niagara, take water from the Power Company's canals at the rate of $10 a horse-power, and manufacture its own electricity; or it would furnish power off the turbine shafts at $13, or electricity at the power-house at $18. But if the Power Company undertook to do anything of this sort, it would not contract to deliver less than 10,000 horse-power; hence, Buffalo must agree to take at least that much or none at all. The Niagara people would not accept a franchise to operate a line to and in Buffalo for a shorter time than that for which its own bonds have been issued. No price is given for electricity delivered at a central station in the suburbs of that city, fifteen miles from the Falls, so that the company's own estimate of the probable waste and cost of transmission is still withheld. There would be four kinds of losses: (1) In transforming at the power house up to a high voltage, (2) on the line, (3) in transforming down at Buffalo, and (4) in distribution over street lines to consumers. These could not well amount to less than twenty or thirty per cent. altogether, and they might, perhaps, reach fifty or sixty per cent. But if, for example, they amounted to just one-half, the $18 rate at the generator shaft would mean $36 to the consumer, without adding anything either for interest on the cost of the transmission plant or for operating expenses. This, however, is probably an extravagant estimate. The prices actually given, by the way, are for a twenty-four hour daily supply. Some establishments require power, however, for only ten or eleven hours. Whether it would pay to put in storage batteries to utilize the surplus is a question which their managers must naturally consider. Richard Hammond writes to the *Buffalo Courier* to say that steam-power, on a scale of 1,000 horse-power, for ten hours daily, can be generated in Buffalo, where coal is very cheap, for $21 per horse-power. The Power Company, however, denies this, and estimates the cost at $32, besides quoting various experts as estimating the cost on a twenty-four hour basis at between $45 and $60. In some other cities, where coal is more expensive, it is said to be from $60 to $75. If, after this discussion, Buffalo decided neither to buy on the terms offered, nor to let the Power Company bring in its own lines and supply the market, more distant cities may possibly be deterred by her example from patronizing the Niagara concern; but as the latter supplies its local customers with electricity at $20 per horse-power, in large quantities, there may be a greater industrial development at the Falls than would otherwise result.

PRODUCTION OF SLATY CLEAVAGE IN AMORPHOUS CELLULOSE.

About a year ago the *Journal* printed an account of the interesting discovery by Messrs. Cross, Bevan and Beadle, of certain derivatives of cellulose, which appeared to be adapted to many useful purposes in the arts. The expectations of the discoveries in this respect promise to be fully realized.

In connection with the development of the discovery in its numerous practical applications, Mr. Clayton Beadle made the following singular observation, which he has communicated to the *Chemical News*, viz.:

A cellulose coagulum obtained by the spontaneous decomposition of cellulose thiocarbonate when cut in sections by a knife, can be readily freed from by-products by suspending the sections in water. The sheets so obtained consist of 15 per cent. of cellulose and 85 per cent. of water of hydration. They are of a soft, flexible nature, like rubber. We find that the dehydration can be effected by the application of high pressure, and that a compact, horny sheet can be obtained by this means, containing 10 per cent. of atmospheric moisture. The original coagulum is homogeneous; but, on the application of pressure, under certain conditions, it is found to exhibit slaty cleavage. On tearing, the edge of the film is found to consist of laminæ of uniform thickness. By varying the mode of applying the pressure and other conditions of treatment, it appears the laminæ may be made to vary in thickness. Sometimes the films are found to consist of two laminæ of equal thickness, and sometimes of a number. Films may be obtained which do not appear to exhibit this property. It appears that when the material is dehydrated by the application of pressure, that it does not always tend to compact itself with one film, but often into laminæ, and that their thickness varies with the conditions of the pressure. In order to avoid slaty cleavage in the production of these films, it is necessary to press under conditions that would tend to give rise to laminæ of a thickness greater than that of the ultimate film obtained. Slaty cleavage may be very much increased by passing the dry, thick sheets a large number of times under high pressure between iron rollers.

IRON AND STEEL PRODUCTION IN THE UNITED STATES IN 1894.

The annual report of the American Iron and Steel Association shows that the shipments of iron ore from the Lake Superior mines, in 1894, amounted to 7,748,932 gross tons, against 6,060,492 tons in 1893, an increase of 1,688,440 tons. Our imports of iron ore in 1894 amounted to 167,307 gross tons, against 526,951 tons in 1893, a decrease of 359,644 tons. The imports in 1894 were the smallest since 1878.

The production of pig iron in 1894 was 6,657,388 gross tons, against 7,124,502 tons in 1893, a decrease of 467,114 tons. The production in the first half of 1894 was 2,717,983 tons, and in the last half 3,939,405 tons. Of the total production in 1894 only 222,422 tons were made with charcoal and only 120,075 tons with anthracite alone. Of the total production 3,808,567 tons, or over 57 per cent., were of Bessemer. In 1893 the Bessemer pig iron produced was about 50 per cent. of the total production. The imports of pig iron in 1894 amounted to 15,582 gross tons, which was the smallest annual importation of which we have any record. The largest annual production of pig iron in the United States was in 1890, when it amounted to 9,202,703

gross tons. In 1892 the next largest production was attained, namely, 9,157,000 tons.

The production of Bessemer steel ingots in 1894 was 3,571,313 gross tons, against 3,215,686 tons in 1893, an increase of 355,627 tons. Of the total production in 1894, 1,664,954 tons were produced in the first half of the year, and 1,906,359 tons in the second half. The largest production of Bessemer steel ingots yet attained in this country was in 1892, when 4,168,435 tons were made. The production of open-hearth steel ingots and direct castings in 1894, was 784,936 gross tons, against 737,890 tons in 1893, an increase of 47,046 tons. The production of crucible steel ingots in 1894 was 51,702 gross tons, against 63,613 tons in 1893, a decrease of 11,911 tons.

The production of all kinds of rails in 1894 was 1,021,772 gross tons, against 1,136,458 tons in 1893, a decrease of 114,686 tons. Included in the above total of rails produced in 1894 were 157,457 tons of street and electric rails, against a similar production in 1893 of 133,423 tons, showing an increase in 1894 of 24,034 tons. The production of rails reached its maximum in 1887, when 2,139,640 gross tons were made. The production of iron and steel structural shapes in 1894, not including plate girders, was 505,901 gross tons, against 387,307 tons in 1893 and 453,957 tons in 1892. The production of plate and sheet iron and steel in 1894, excluding nail plate and also excluding skelp iron and steel, amounted to 682,900 gross tons, against 674,345 tons in 1893 and 751,460 tons in 1892.

The production of wire rods in 1894 was 673,402 gross tons, against 537,272 tons in 1893 and 627,829 tons in 1892. The production of wire nails in 1894 was 5,681,801 kegs of 100 pounds, against 5,095,945 kegs in 1893, an increase of 585,856 kegs. The production of cut nails and cut spikes in 1894 was 2,425,060 kegs, against 3,048,933 kegs in 1893, a decrease of 623,873 kegs.

BOOK NOTICES.

Ethics of Literature.—By John A. Kersey, Marion, Ind. Author, 1894.

In many respects this production is a remarkable one, and, on its merits, deserves to be accorded a permanent place in the annals of our contemporaneous literature. The author, evidently, has been not only an omniverous reader, but, also, unlike most of that genus, shows himself to be a thoughtful, original and discriminating critic.

His ethics may, perhaps, best be described as a stout protest against the prevalence of intellectual cant and fraud, which has its origin in the blind and stupid acceptance of authority, as the substitute for the exercise of individual judgment.

The author's grievance, unfortunately, is as ancient as history, and will doubtless continue to the end of time, to give the free thinker in philosophy,

science and religion, his justification for running amuck among the men and things that evoke his inspired fury.

Even the most independent in thought among us will find himself the better for the sort of mental shaking-up and brushing away of cobwebs, to which Mr. Kersey treats us. For it is a lamentable truth that most of us are altogether too willing to accept opinions at second-hand, provided that they bear the trade-mark of respectability. It is much less tiresome to drift with the current than to swim against it.

The onset of this free lance, therefore, has the refreshing interest of novelty, and the reader rises from the perusal of a chapter of the ethics with the feeling of mental stimulation. Now, the reader is conscious of a rude shock to tender sensibilities, as some keen thrust of the author pierces through an armor believed to be of proof; and again he is gratified to find his own half-formed convictions strengthened or confirmed by the author's deft and subtle analysis, or by some incisive criticism or brilliant flash of satire. W.

Practical Telegraphy: A book for self-instruction. By F. E. Wessels, E.S., Philadelphia. Author, 1895. Price, 50 cents.

The object of this pamphlet, as declared on the title page, is to furnish the would-be telegrapher a practical manual for self-instruction. The author, after giving a short sketch of the work of Morse, proceeds to the consideration of the fundamental principles of the electric telegraph, and the mode of action and care of batteries.

Following these come very full instructions in the practice of the art of telegraphy, with illustrations of forms used in commercial and railroad work, tables of abbreviations, etc. The booklet appears well adapted for its intended purpose. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 15, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 15, 1895.

Mr. H. R. HEYL, Vice-President, in the chair.

Present, seventy-three members and seventeen visitors.

Additions to membership since last report, seventeen.

The Secretary reported progress on behalf of the special committee on International Standard for Screw-threads.

The paper of the evening was read by Mr. Arthur Kitson, member of the Institute, on the "Ball Nozzle," a new invention for spraying water, devised

by Mr. Charles V. Pollock, of New York. Mr. Kitson gave an account of the construction of the device and of the various uses to which it has been applied, and offered an explanation of the principle of its operation. The subject evoked considerable discussion. The speaker illustrated his remarks by exhibiting a number of ball nozzles applied to firemen's hose, lawn sprinklers, etc., and showed one of the smaller sizes of nozzles in operation.

On Mr. Colvin's motion, numerously seconded, the meeting passed a vote of thanks to Mr. Kitson for his interesting communication.

On Mr. Chorman's motion, which was also numerously seconded, the subject of Mr. Pollock's invention was referred to the Committee on Science and the Arts for investigation and report.

The Chairman made some remarks apropos to the new building plan, on which the Board of Managers is seriously engaged; giving an account of the steps which have thus far been taken to carry the plan into effect.

The Secretary presented his monthly report, of which an abstract appears in the *Journal.*

Adjourned.

WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR JANUARY, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 31, 1895.

GENERAL REVIEW.

The average temperature for January, 1895, 24°·2, is 4°·4 below the average [28°·6] for the past seven years.

Most of the highest recorded temperatures occurred on the 7th, 11th and 21st, and were as follows: Pittsburgh, 58°; Uniontown, 58°; Lancaster, 57°; Erie, 55°; Philadelphia, 55°, and Immel Reservoir, 55°.

The lowest were on the 1st, 5th, 13th, 14th, 27th, 28th and 31st: Emporium, minus 17°; Smethport, minus 16°; Wellsboro, minus 16°; Shingle House, minus 15°; Lewisburg, minus 15°, and Dyberry, minus 15°.

From January 1, 1895, to January 31, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 48°; at Erie, 70°, and at Pittsburgh, 83°.

For the same period the excess in precipitation, in inches, at Philadelphia, was 1·15; Pittsburgh, 0·93, and a deficiency at Erie of 0·01.

TEMPERATURE.

		Mean Temperature.	*Mean Precipitation, Inches.*
January,	1888,	22°·1	4·19
	1889,	31°·9	3·54
	1890,	37°·7	3·04
	1891,	30°·6	3·64
	1892,	26°·3	4·77
	1893,	19°·3	2·85
	1894,	32°·7	2·29
	1895,	24°·2	4·17

The means of the daily maximum and minimum temperatures, 32°·8 and 15°·5, respectively, give a monthly mean of 24°·2, which is 8°·5 below the corresponding month of 1894.

The average daily range was 17°·3.

Highest monthly mean, 30°·8 at *Philadelphia* [Centennial Avenue].

Lowest monthly mean, 16°·8 at Shingle House.

Highest temperature recorded during the month, 58° on the 21st at Pittsburgh and Uniontown.

Lowest temperature, minus 17° on the 31st at Emporium.

Greatest local monthly range, 65° at Cassandria and Uniontown.

Least local monthly range, 41° at Coopersburg.

Greatest daily range, 51° at Saegerstown.

PRECIPITATION.

The average precipitation for the State, for the month, 4·17 inches, is 0·70 inches more than the average [3·47] for the last seven years.

General precipitation (mostly snow) occurred on the 6th, 7th, 8th, 9th, 10th, 11th, 13th, 16th, 21st, 22d, 26th and 29th.

The average snowfall during the month was 14·2 inches, and 10·7 inches remained on the ground at the end of the month.

The largest totals of snowfall in inches were: Somerset, 32; Lock Haven, 29; Grampian, 28; Cassandria, 27; Emporium, 26, and Wellsboro, 25.

The largest monthly totals of rainfall and melted snow in inches were: Somerset, 6·36; Smethport, 5·90; Hamburg, 5·82; Hollidaysburg, 5·74; Pottstown, 5·65, and Phœnixville, 5·47.

The least were: Shingle House, 1·83; Towanda, 1·95; South Eaton, 2·35; Dyberry, 2·95; Confluence, 2·98, and Chambersburg, 3·00.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 13; clear days, 7; fair days, 10; cloudy days, 14.

BAROMETER.

The mean pressure for the month, 30·06, is about ·04 below the normal. At the United States Weather Bureau Stations, the highest observed was 30·54 at Erie on the 8th, and the lowest 29·24 at Erie on the 26th.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—Hollidaysburg, 5th; Johnstown, 6th; Mauch Chunk, 26th; Uniontown, 6th; Lebanon, 5th, 26th; South Bethlehem, 26th; Easton, 26th; Aqueduct, 6th; Somerset, 6th; Lewisburg, 6th.

Hail.—Towanda, 6th, 10th; Emporium, 6th, 10th; Mauch Chunk, 6th, 10th; Phœnixville, 6th, 25th; Grampian, 5th; Lock Haven, 6th, 10th; Carlisle, 6th; Lebanon, 5th, 10th, 16th; Easton, 6th, 16th; Dyberry, 6th, 26th.

Snow.—Hamburg, 29th; Hollidaysburg, 2d, 6th, 10th, 13th, 16th, 26th, 28th, 29th; Towanda, 4th, 5th, 6th, 10th, 13th, 14th, 16th, 17th, 18th, 22d, 25th, 29th, 30th; Quakertown, 3d, 4th, 6th, 8th, 9th, 10th, 13th, 16th, 19th,

22d, 23d, 26th, 28th, 29th, 30th; Cassandria, 2d, 8th, 10th, 13th, 16th, 19th, 22d, 23d, 27th, 29th; Johnstown, 2d, 4th, 8th, 10th, 11th, 12th, 13th, 14th, 15th, 16th, 18th, 19th, 22d, 23d, 24th, 25th, 26th, 27th, 28th, 29th, 30th; Emporium, 1st, 3d, 4th, 5th, 6th, 10th, 13th, 14th, 15th, 16th, 17th, 18th, 19th, 21st, 22d, 23d, 24th, 25th, 26th, 28th, 29th, 30th; Mauch Chunk, 3d, 9th, 10th, 13th, 16th, 19th, 26th, 29th; State College, 2d, 3d, 6th, 8th, 10th, 11th, 13th, 14th, 16th, 17th, 18th, 22d, 23d, 25th, 26th, 28th, 30th; West Chester, 9th, 13th, 29th, 30th; Coatesville, 3d, 4th, 8th, 9th, 13th, 16th, 22d, 26th, 29th, 30th; Kennett Square, 3d, 8th, 9th, 10th, 13th, 28th, 29th; Phœnixville, 2d, 3d, 9th, 28th, 29th; Grampian, 2d, 4th, 5th, 10th, 13th, 16th, 22d, 26th, 29th, 30th; Lock Haven, 6th, 10th, 13th, 14th, 16th, 19th, 21st, 25th, 26th, 29th; Saegerstown, 1st, 3d, 4th, 9th, 12th, 13th, 14th, 15th, 19th, 23d, 24th, 26th, 29th; Carlisle, 3d, 8th, 13th, 26th, 29th; Harrisburg, 3d, 8th, 10th, 13th, 19th, 26th, 28th, 29th; Uniontown, 2d, 4th, 8th, 12th, 13th, 25th, 28th; Chambersburg, 2d, 8th, 13th, 25th, 28th, 29th; Huntingdon, 2d, 8th, 10th, 13th, 16th, 19th, 22d, 25th, 29th; Lancaster, 2d, 8th, 14th, 17th, 26th, 29th; Lebanon, 2d, 3d, 8th, 9th, 10th, 13th, 16th, 19th, 22d, 23d, 26th, 28th, 29th, 30th; Coopersburg, 3d, 4th, 8th, 9th, 13th, 16th, 29th; Drifton, 2d, 4th, 10th, 16th, 18th, 27th, 28th; Wilkes-Barre, 8th, 16th, 26th, 29th; Greenville, 3d, 4th, 6th, 13th, 14th, 24th, 28th; Pottstown, 3d, 25th, 29th; South Bethlehem, 8th, 16th, 26th, 28th, 29th; Easton, 8th, 13th, 16th, 19th, 26th, 29th, 30th; Aqueduct, 2d, 8th, 10th, 13th, 16th, 19th, 22d, 23d, 25th, 26th, 29th, 30th; *Philadelphia* [Centennial Avenue], 3d, 9th, 28th, 29th; Blooming Grove, 8th, 10th, 13th, 16th, 18th, 29th; Shingle House, 2d, 4th, 14th, 18th, 22d, 26th; Somerset, 7th, 9th, 12th, 15th, 18th, 23d, 25th, 26th, 28th, 29th; Wellsboro, 5th, 10th, 13th, 16th, 19th, 26th, 28th; Lewisburg, 13th, 16th, 19th, 26th, 28th, 29th; Dyberry, 3d, 4th, 5th, 6th, 8th, 10th, 13th, 14th, 16th, 19th, 26th; Honesdale, 4th, 5th, 6th, 10th, 13th, 16th, 19th, 26th, 29th; Salem Corners, 4th, 6th, 8th, 9th, 10th, 13th, 16th, 17th, 19th, 22d, 23d, 26th, 29th; Lycippus, 3d, 13th, 17th, 23d, 29th; South Eaton, 6th, 10th, 13th, 16th, 17th, 23d, 26th, 29th; York, 2d, 3d, 8th, 9th, 10th, 12th, 13th, 16th, 19th, 25th, 28th, 29th.

Sleet.—Hollidaysburg, 6th, 10th, 20th; Towanda, 6th, 10th, 25th; Cassandria, 6th, 25th; Johnstown, 5th; Emporium, 6th; Mauch Chunk, 6th, 10th, State College, 6th; Grampian, 6th; Lock Haven, 6th, 10th; Saegerstown, 25th; Lebanon, 5th; Coopersburg, 6th, 16th; Wilkes-Barre, 25th, 26th; Greenville, 5th; Aqueduct, 5th, 25th; *Philadelphia* [Centennial Avenue], 8th, 25th; Somerset, 5th, 25th; Dyberry, 6th, 10th; Honesdale, 26th; York, 6th, 10th, 25th.

Aurora.—Hollidaysburg, 11th; Le Roy, 19th; Saegerstown, 2d.

Solar Halo.—Le Roy, 9th, 28th; *Philadelphia* [Centennial Avenue], 5th, 7th, 25th.

Lunar Halo.—Le Roy, 9th; Towanda, 2d, 9th; *Philadelphia* [Weather Bureau], 5th, 15th; [Centennial Avenue], 5th.

Meteors.—*Philadelphia* [Centennial Avenue], 29th.

Parhelias.—Le Roy, 14th, 24th; Towanda, 24th.

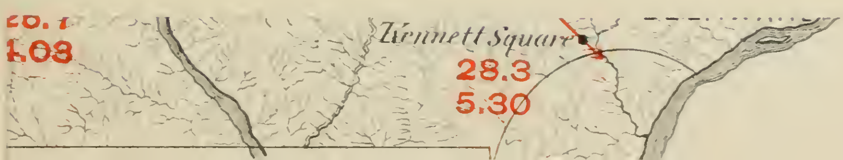
Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for January, 1895.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR JANUARY, 1895.

County.	Station.	Elevation above Sea Level (feet).	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers
Allegheny,	Pittsburgh,	820	27·0	58	21	—5	13	34·3	19·4	14·9	42	4·16	8·3	...	21	7	9	15	W	O. D. Stewart, W. B.
Berks,	Hamburg	380	26·2	47	6	2	13	32·8	19·7	13·1	30	5·82	3·0	...	10	5	17	9	W	William Shipe.
Berks,	Reading,[3]	280	25·4	...	...	...	...	...	...	...	...	3·90	...	...	15	...	...	...	...	Franklin Yager.
Blair,	Altoona (30 days),	1,181	33·9	68	24	9	5	42·5	25·3	17·2	47	3·22	...	...	13	...	...	...	...	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	21·9	47	7	—11	5, 31	33·0	10·8	22·2	44	5·74	21·0	10·0	14	11	5	15	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	18·9	46	7	—4	13, 28	26·6	11·2	15·4	26	3·27	21·7	16·0	14	4	7	20	SW	G. W. T. Warburton.
Bradford,	Towanda,	754	19·0	44	7	—16	1	28·1	10·0	18·1	33	1·95	20·5	8·0	9	5	10	16	W	Hiram E. Bull.
Bucks,	Forks of Neshaminy,	304	31·4	...	...	...	...	...	...	...	...	4·98	5·0	...	11	20	1	10	W	J. C. Hilsman.
Bucks,	Quakertown,	536	25·4	50	7	2	5	33·5	17·2	16·3	31	3·73	8·0	3·0	11	4	18	9	NW	J. L. Heacock.
Cambria,	Cassandria	2,100	22·4	51	7	—14	31	28·9	15·9	13·0	40	4·71	27·0	15·0	12	...	12	19	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	25·0	48	21	—5	13	33·0	16·9	16·1	36	4·91	15·0	8·0	20	3	5	23	NW	E. C. Lorentz.
Cameron,	Emporium,	1,050	19·5	43	11	—17	31	29·3	9·7	19·6	37	4·79	25·9	15·0	16	3	13	15	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	22·8	43	7	1	5, 13	32·0	13·6	18·4	32	5·06	13·5	8·0	14	11	7	13	N	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	21·8	46	7	—5	5, 13	30·7	13·0	17·7	33	4·18	23·8	17·0	14	6	9	16	W	Prof. Wm. Frear.
Chester,	West Chester,	455	27·9	49	11	7	13	35·2	20·6	14·6	33	4·95	6·8	2·0	13	12	4	15	NW	J. C. Green, D.D.S.
Chester,	Coatesville,	380	27·2	48	7	5	5	35·9	18·6	17·3	31	5·08	7·2	4·0	15	8	15	8	W	W. T. Gordon.
Chester	Kennett Square,	275	28·3	51	7	7	5	37·4	19·2	18·2	31	5·30	8·5	5·0	13	9	9	13	NW	B. P. Kirk.
Chester,	Phœnixville,	190	27·7	50	7	5	13, 14	35·2	20·2	15·0	32	5·47	12·0	8·0	16	7	4	20	NW	Knowles Croskey.
Chester,	Westtown ‡,	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	John D. Carter.
Clearfield,	Grampian,	1,450	18·7	50	7	—12	31	25·5	11·9	13·6	32	5·10	28·0	24·0	15	1	17	13	W	Nathan Moore.
Clinton,	Lock Haven,[1]	560	20·4	49	11	—13	31	...	...	...	...	4·73	29·1	10·0	12	3	2	26	W	Prof. J. A. Robb.
Crawford,	Saegerstown,	1,200	21·2	50	21	—12	31	32·3	10·1	22·2	51	3·92	18·0	8·0	10	3	11	17	SW	J. G. Apple.
Cumberland,	Carlisle,	480	24·2	45	11	2	5	32·3	16·1	16·2	31	3·74	10·5	8·0	11	11	8	12	W	J. E. Pague.
Dauphin,	Harrisburg,	480	25·0	44	7	2	13	31·0	20·0	11·0	25	3·80	9·5	7·0	15	6	12	13	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College†,	361	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	19·4	45	21	4	17, 27	...	...	...	...	...	...	12·0	...	...	...	...	SW	C. F. Sweet.
Erie,	Erie,	1,400	24·0	55	21	—5	13	32·0	16·0	16·0	27	3·51	...	...	18	2	10	19	SW	P. Wood, W. B.
Fayette,	Uniontown,	681	27·7	58	21	—7	13	35·2	20·2	15·0	33	4·89	14·0	...	17	5	16	10	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	24·0	46	19	—3	1, 5	33·0	15·1	17·9	35	3·00	7·0	...	13	10	3	18	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	24·2	45	19	—7	5	33·9	14·5	19·4	41	5·16	15·5	10·0	10	1	21	9	W	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	28·1	57	7	1	1	39·1	17·1	22·0	44	4·17	7·8	3·5	9	11	11	9	W	A. V. Heister.
Lebanon,	Lebanon,	458	24·0	44	7	0	31	32·8	15·2	17·6	34	4·70	15·1	4·5	16	6	13	12	NE	G. W. Hayes, C. E
Lehigh,	Coopersburg,	520	27·0	46	7	5	5	35·4	18·7	16·7	29	4·19	7·3	3·0	14	12	6	13	SW	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	25·1	49	7, 11	—3	23	39·2	11·0	28·2	48	1·69	8·0	11·0	9	6	4	16	...	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	24·4	47	7	—2	1	33·5	15·4	18·1	36	3·43	13·0	8·0	7	16	4	11	W	A. W. Betterly.
McKean,	Smethport,	1,500	18·9	47	7	—16	31	27·7	10·1	17·6	44	4·10	20·5	...	10	6	11	14	SW	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	21·0	51	21	—10	5	31·1	10·8	20·3	49	3·50	35·5	6·0	12	5	6	20	...	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	27·4	49	7	6	5	33·7	21·0	12·7	24	5·65	4·5	2·0	9	9	10	12	NW	Charles Moore, D.D.S.
Northampton,	Bethlehem,	...	...	...	...	...	...	...	...	...	...	4·04	...	...	...	...	...	...	...	J. E. Luckenbach.
Northampton,	South Bethlehem,	339	24·8	48	7	5	5	31·5	18·1	13·4	24	...	6·0	4·0	...	6	10	15	NW	T. Merriman.
Northampton,	Easton— Lafayette College,	325	25·0	49	7	0	5	33·1	16·9	16·2	32	3·56	7·2	...	8	9	10	12	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	25·8	50	7	—1	1	34·6	17·1	17·5	30	3·72	11·8	6·0	14	11	10	10	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	30·6	55	7	10	13, 14	37·2	24·0	13·2	26	4·52	4·6	2·8	13	8	11	12	NW	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	30·8	53	7	11	5	37·4	24·2	13·2	26	5·06	4·8	3·0	13	7	13	11	NW	John Comly.
Pike,	Blooming Grove,*[1]	...	21·3	46	7	—6	5	...	...	...	...	3·92	15·0	20·0	8	9	12	10	W	John Grathwohl.
Potter,	Shingle House,	1,475	16·8	44	21, 22	—15	31	26·9	6·8	20·1	38	1·83	15·8	18·0	7	8	8	15	NW	H. L. Pearsall.
Snyder,	Selins Grove‡,	455	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. M. Boyer.
Somerset,	Somerset,	2,250	18·9	48	21	—13	12	27·8	10·0	17·8	36	6·36	32·0	10·0	14	1	10	20	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	18·6	45	7	16	31	...	...	...	...	3·00	25·0	30·0	9	3	9	19	SW	H. D. Deming
Union,	Lewisburg	450	18·9	44	11	—15	1	31·1	6·7	24·4	38	3·15	14·0	10·0	12	2	5	24	W	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	18·2	47	7	—15	5	29·2	7·2	22·0	38	2·95	19·0	22·0	13	6	8	17	W	Theodore Day.
Wayne,	Honesdale,	1,000	22·5	49	7	—12	1	31·9	13·1	18·8	37	3·68	16·5	19·0	14	12	12	7	NW	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	22·6	50	7	—4	13	31·2	14·0	17·2	34	4·42	24·4	30·0	15	6	10	15	W	T.B. Orchard, M D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	24·1	55	7	—9	14	32·4	15·8	16·6	45	4·66	12·8	...	13	...	...	...	...	Murray Forbes
Wyoming,	South Eaton,	660	21·6	47	7	11	1	31·2	12·1	19·1	36	2·35	12·5	15·0	10	8	7	16	NW	B. M. Hall.
York,	York,	385	25·7	47	7	1	1	33·9	17·5	16·4	35	4·03	9·5	2·5	14	7	16	8	W	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [3] Mean temperature 8 + 8 ÷ 2.
† No records. ‡ Records incomplete.

2	3	4	5	6	7	8	9	1
.	·03	·01	. .	·87	·62	·14	. .	·7
.	. .	·10	. .	·17	·61	·05	. .	·1
.	. .	. .	. .	·84	·36	. .	. .	[illegible]
.	·05	·04	. .	·63	·99	·21	. .	[illegible]
01	·09	·01	·57	·10	·23	·04	·03	[illegible]
.	·03	. .	. .	·48	·59	·20	. .	[illegible]
.	·05	·07	. .	1·18	·72	·18	. .	[illegible]
.	. .	. .	. .	·80	·65	·12	. .	[illegible]
.	·10	·06	. .	·74	·90	·20	. .	[illegible]
.	·05	·03	. .	·40	·90	·20	·14	[illegible]
.	·50	·40	. .	·30	·16	·40	. .	[illegible]
.	·15	. .	. .	·73	·62	·15	·07	[illegible]
02	. .	·02	. .	1·67	·28	·07	. .	[illegible]
.	·11	·04	. .	·47	·48	·12	.	[illegible]
.	. .	·24	. .	1·40	·76	·08	. .	[illegible]
.	. .	·07	. .	·94	·50	·27	. .	[illegible]
.	. .	·06	·01	·60	·65	·21	. .	[illegible]
03	·01	·03	·01	·86	·40	·02	. .	1·
.	. .	·09	. .	·82	·55	·20	. .	[illegible]
.	. .	·22	·95	·40	. .	. .	·50	[illegible]
.	·07	·05	. .	·64	·66	·40	. .	[illegible]
20	. .	·06	. .	. .	. .	. .	. .	[illegible]
.	. .	·15	. .	·50	·50	·25	. .	[illegible]
.	. .	. .	1·30	·55	·21	. .	·60	.
.	. .	·20	. .	·15	·21	·36	·22	[illegible]
02	. .	·01	. .	1·16	·24	·33	·04	[illegible]
.	. .	·10	. .	·72	·31	·14	. .	[illegible]
.	·12	·03	. .	·27	·65	·20	·02	[illegible]
02	. .	. .	. .	·45	·06	·57	. .	[illegible]
.	. .	·10	. .	·14	·10	. .	. .	1



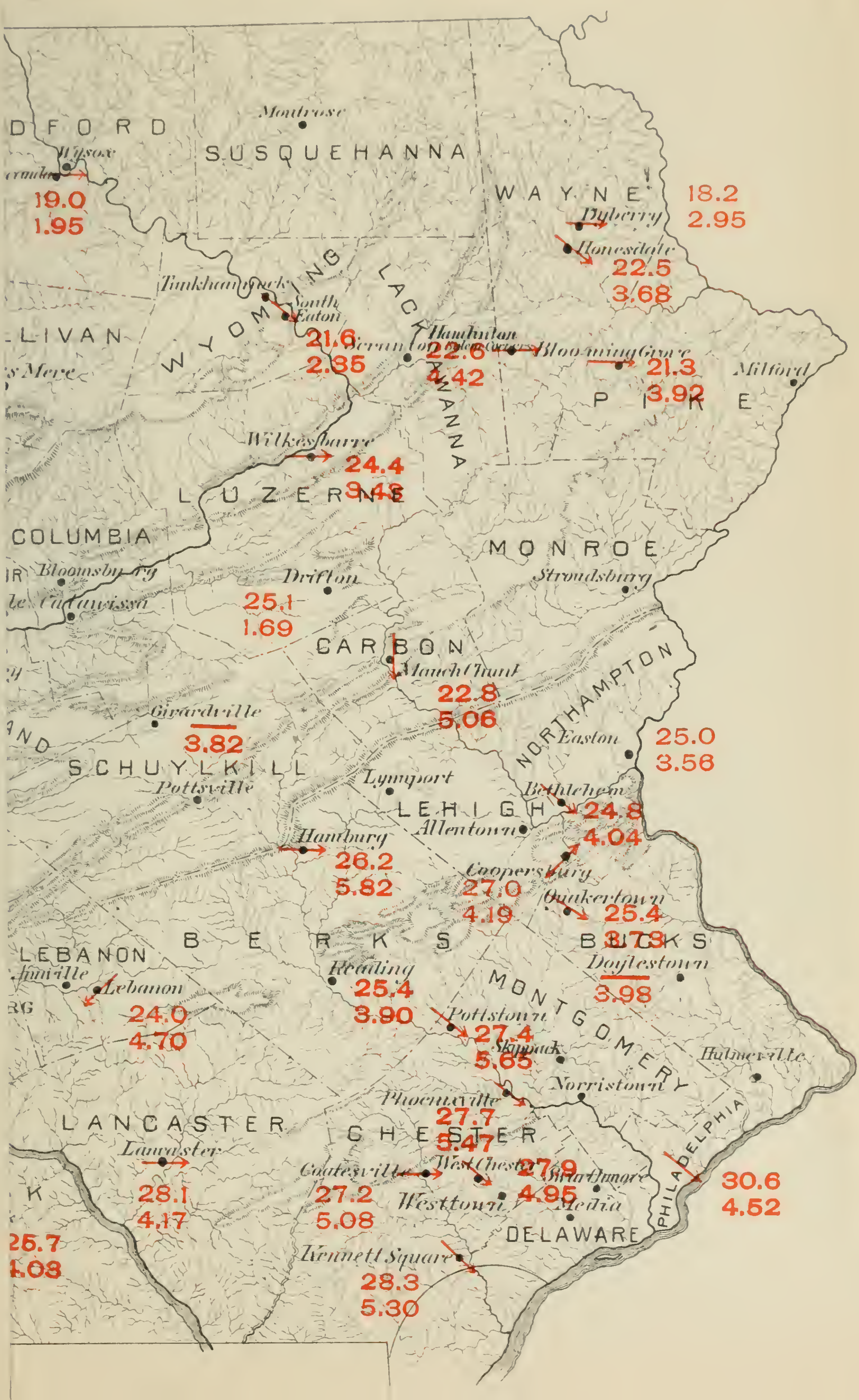
PRECIPITATION DURING JANUARY, 1895.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin																																
Bethlehem,			.83				.34		.98							.51					.05					1.12			.19			4.04
Blooming Grove,								.76		.20	.86		.10			.55		.22								.93			.30			3.92
Browers Lock,			.08				.74	.14	.13	.21	.55		.83			.64						.08				1.78			.30			4.82
Coatesville,			.01	.01		.77	.02	.27	.05	1.04	.09		.05			.91					.08	.03				1.30		.20	.25			5.08
Coopersburg,			.08	.02		.85	.02	.27	.05	.51	.41		.14			.43					.05	.03				1.18			.21			4.19
Doylestown,						.75		.17	.07	.46	.27					.62					.09					1.32			.23			3.98
Dyberry,					.10	.01	.22	.11		.21	.10		.10			.34		.10	.30		.09					.65			.02			2.95
Easton,								.94			.98		.02			.31			.01			.02				1.08			.20			3.56
Forks of Neshaminy			.06			.67		.38		.80	.03		.12	.04		.62					.09					2.00			.17			4.98
Frederick,			.02			.72		.25		.40	.33		.19			.46					.06	.03				1.44			.29			4.19
Hamburg,		.40				1.40	.11	.50		.89			.18			.46					.19					1.40			.29			5.82
Honesdale,				.02	.10	.62	.21	.09		.53	.32		.14			.38			.07		.34	.01				.80			.05			3.68
Kennett Square			.04			.66	.04	.10	.16	.88	.18		.02			.70					.13					1.89		.10	.40			5.30
Lansdale,			[illegible]			.75		.33	.05	.73	.31		.20			.60					.05					1.61			.41			5.09
Mauch Chunk,			.04			.95	.16	.25	.05	.35	.90		.33			.47			.10		.04	.02				1.25			.15			5.06
Ottsville,						.75	.05	.33		.44	.50					.39										1.29			.18			3.93
Philadelphia, a†			.01			.35	.01	.08	.10	.93	.25		.22			.69					.09					1.20		.07	.32			4.52
Philadelphia, b.			.01			.34	.02	.12	.11	.93	.24		.19			.80					.08					1.65		.07	.30			5.06
Phoenixville.		[illegible]				.78	.01	.26	.10	.63	.23		.30			.75			.03		.12	.07	.01			1.69		.08	.30			5.47
Point Pleasant,						.64		.27	.12	.70	.46		.08			.53					.13					1.44			.26			4.03
Pottstown,		.05				1.20		.15		1.40						.70					.15				.10	1.60			.30			5.65
Quakertown,						.47	.05	.12	.23		.55		.07			.56			.03			.13				1.30			.22			3.73
Reading,			.01			.83	.06	.36	.06	.55	.22		.17			.45			.01		.01	.02				.92		.01	.22			3.90
(Salem Corners) Hamilton,				.05		.53	.22	.14	.04	.37	.71		.30			.50	.10		.27			.05	.02			.97			.15			4.42
Seisholtzville,						.92		.38	.04	.76	.31					.56					.11					1.07			.25			4.40
Smith's Corner,						.77		.30	.07	.64	.32		.09			.39					.06					1.38			.25			4.47
Swarthmore,																																
West Chester,			.12			.62	.02	.20	.05	.67	.18		.31			.39					.09					1.74		.19	.27			4.95
Westtown,							§																									
Susquehanna Basin.																																
Altoona,						.79	.28	.04		.60	.07	.10	*	.17		.27			.02		.15	.17				.48			.08			3.22
(Aqueduct) Logania,		.03				.55	.10	.45		.57	.18		.17			.43			.06		.11	.03				.87		.03	.14			3.72
Carlisle,			.08			.78	.05	.20	1.10	.18	.05		.25			.52										.28			.25			3.74
Drifton,	*	.10		.05		*	.54			.20	.35		*			.20		.15		*							.05	.05				1.69
Emporium,				.03		.78	.92	.12		.35	.30		.55			.20		.03	.30		.15	.04			.06	.91		.03		.02		4.79
Girardville,				.13		.44	.28	.21		.90			.26			.45					.14	.09	.04		.26	.26		.12	.24			3.82
Grampian,		.03		.10	.44	1.18	.70			.75	.14		.28			.28			.32		.24	.13				.48			.06	.05		5.10
Harrisburg,†			.10			.94	.04	.19	.03	.68	.19		.02			.44			.01		.12	.03				.79		.08	.14			3.80
Hollidaysburg,		.04				.88	.42	.10		.90	.22		.70			.41			.34		.20	.09				1.27		.12	.05			5.74
Huntingdon,		1.25						.13		1.01			1.18			.23			.26		.35	.05			.45				.25			5.16
Kilmer,§																																
Lancaster,		.05				2.00		.10			‡	.81		.21			.39					‡	.21			.05		‡	.35			4.17
Lebanon,		.01	.03			1.10	.01	.53	.05	.38	.18		.27			.46			.02		.08	.06				1.18		.05	.24			4.70
Le Roy,				.03		.40	.21	.03		.72	.20		.40			.20			.40		.02	.01				.40			.20	.03		3.27
Lewisburg,						.18	.16	.05		.71	.05		.05			.30			.05		.40					.92		.10	.18			3.15
Lock Haven,						.20	1.05			.60	.77		.40	.10		.40			.50		.01				.20	.30			.20			4.73
Selins Grove,																																
South Easton,						.29	.14	.08		.53	.12		.15			.43						.05				.50			.06			2.35
State College,						.52	.59			.73	.15		.40			.40			.43		.15	.06	.03		.10	.44		.08	.10			4.18
Towanda,						.20	.20	.08		.60			.10			.20		.20							.22				.15			1.95
Wellsboro,					.60	.05				.70	.05		.30			.25			.30							.50		.25				3.00
Wilkes-Barre,							1.51	.40		1.38						.72					.02					.22			.18			3.43
York,			.06			.74	.20	.40	.20	.48	.12		.25			.48			.02		.08					.72		.15	.13			4.03

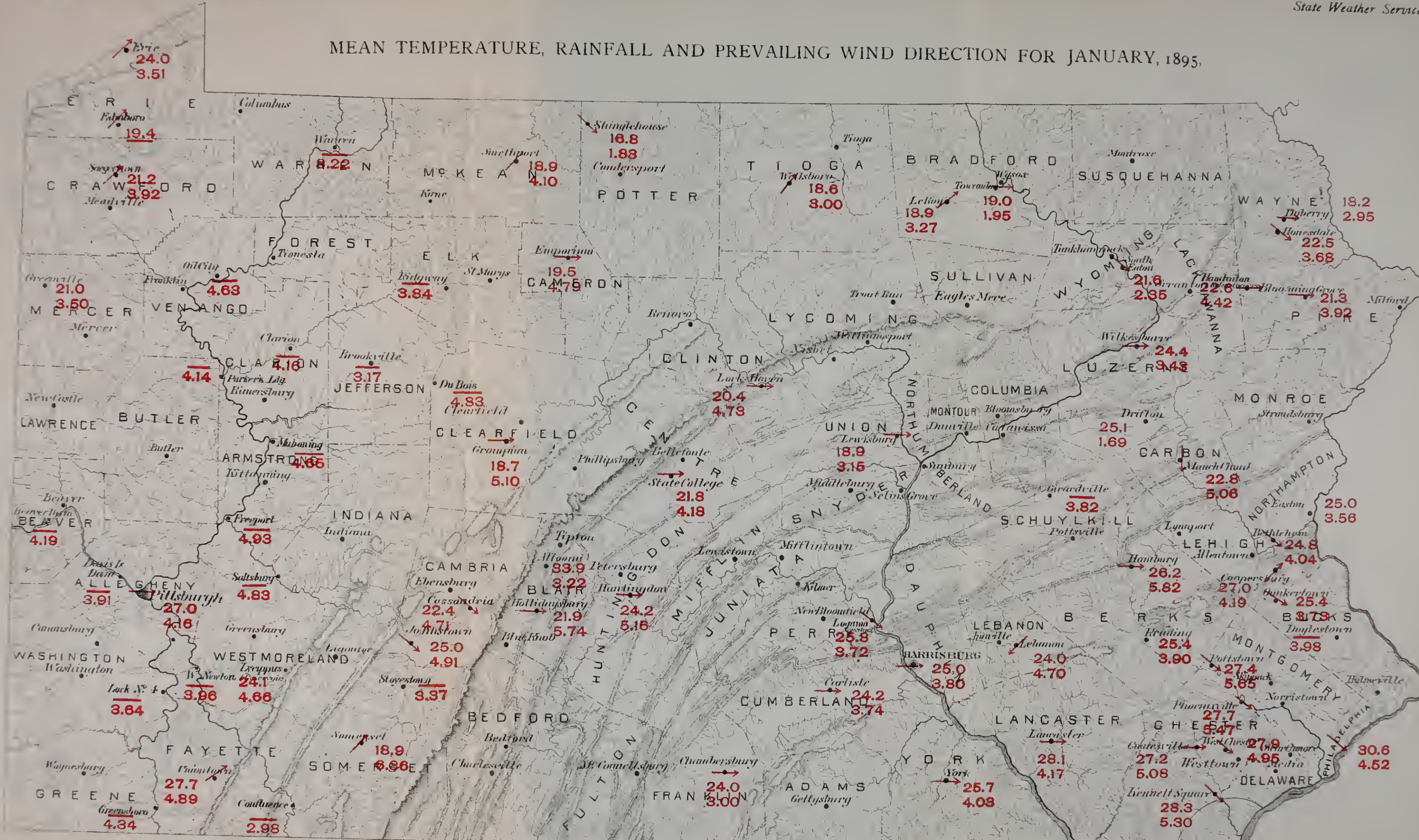
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,			.03	.01		.87	.62	.14		.72	.76		.07	.01		.20			.06		.01	.06				.56			.07			4.19
Brookville,				.10		.17	.61	.05		.14	.45		.32	.25	.02	.12	.04		.18		.02	.22	.05			.24	.04		.12	.03		3.27
Cassandria,						.84	.36			.35	.16		.45			.30			.50		.20	.40	.20				.65		.30			4.71
Clarion,			.05	.04		.63	.99	.21		.38	.32		.31	.07	.03	.13	.04		.35	.01	.07	.12	.03	.01		.14	.04		.12	.06	.01	4.16
Confluence,		.01	.09	.01	.57	.10	.23	.04	.03	.36		.04	.03		.25			.11	.09	.05	.30	.01	.02		.42	.02		.20				2.98
Davis Island Dam,			.03			.48	.59	.20		.58	.67		.10	.10		.40	.07		.05		.06	.03	.05			.40			.10			3.91
DuBois,			.05	.07		1.18	.72	.18		.38		.32	.15			.17		.03				.26	.14			.93	.05		.09	.03	.08	4.33
Elwood Junction,						.80	.65	.12		.33	.91	.21		.03		.02			.19		.50	.09				.40						4.25
Freeport,			.10	.06		.74	.90	.20		.71	.20		.19	.22		.35	.20		.20		.08	.10	.02			.54	.02		.06	.04		4.93
Greensboro,			.05	.03		.40	.90	.20	.14	.70	.35		.18	.02		.45	.05		.03		.05	.13	.02	.01		.45			.16	.02		4.34
Greenville,			.50	.40		.30	.16	.40		.10	.11		.21	.13							.34			.15				.05				3.50
(Immel Reservoir) Lycippus,			.15			.73	.62	.15	.07	‡	1.39		.26				.53		.07			.13	.07			.34			[illegible]			4.66
Johnstown,		.02		.02		1.67	.28	.07		.10	.09	.05	.18			.45		.03	.30		.29	.11	.02		.08	.32		.09	.03	.21		4.91
Lock No. 4,			.11	.04		.47	.48	.12		.62	.70		.12	.03		.43			.03		.03	.10	.01			.20			.15			3.64
Mahoning,				.24		1.40	.76	.08		.41	.55		.23	.05		.13					.14	.20	.06			.29	.01		.08	.02		[illegible]
Oil City,				.07		.94	.50	.27		.32	.61		.32	.30	.02	.05			.30		.02	.21		.02		.55	.06		.06	.01		[illegible]
Parker's Landing,				.06	.01	.60	.65	.21		.32	.80	.01	.18	.10	.04	.13		.01	.32		.08	.09	.03		.01	.30	.04		.11	.04		4.14
Pittsburg,†		.03	.01	.03	.01	.86	.40	.02		1.03	.16	.02	.18	.02		.52			.04		.08	.07			.19	.40		.05	.03	.01		4.26
Ridgway,				.09		.82	.55	.20		.29	.38		.21	.11		.15			.31			.19				.48			.05	.01		3.84
Saegerstown,				.22	.95	.40			.50	.28			.50	.28							.25		.10			.44						3.92
Saltsburg,	.03		.07	.05		.64	.66	.40		.57	.49	.03	.19	.13	.02	.38	.07		.14	.01	.04	.20	.06	.02		.34	.13		.12	.24		4.83
Shingle House,		.20		.06						.25				.30				.32				.10				.60						1.83
Smethport,				.15		.50	.50	.25		.80	.20		.20						.40			.30				.80						4.15
Somerset,					1.30	.55	.21		.60			.91			.42			.24	.30		.25		.12		.60	.54		.22	.10			6.36
Stoyestown,				.20		.15	.21	.36	.22	.71	.17	.10		.15							.20	.20	.10	.10	.20	.10			.20			3.37
Uniontown,		.02		.01		1.16	.24	.33	.04	.84	.06	.25	.09		.22	.63		.06					.03		.26			.65				[illegible]
Warren,				.10		.72	.31	.14		.21	.16		.19	.31	.09			.01	.11	.01		.45	.01			.19	.09		.02	.10		3.22
West Newton,			.12	.03		.27	.65	.20	.02	.50	.74	.02	.19	.05		.41	.13		.04		.06	.13	.04			.22			.14			3.96
Potomac Basin.																																
Chambersburg,		.02				.45	.06	.57		.20	.15		.10			.48					.01				.05	.60		.17	.14			3.00
Lake Basin.																																
Erie,†				.10		.14	.10			1.04	.05	.09	.32	.49	.04			.04	.27		.11	.20		.02		.40	.03	.05		.02		3.51

† U. S. Weather Bureau Stations. * Missing. ‡ Amount included in measurement following. § Discontinued.

TION FOR JANUARY, 1895.



MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR JANUARY, 1895.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR FEBRUARY, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 28, 1895.

GENERAL REVIEW.

The average temperature for February, 1895, 20°·2, is 9°·8 below the average [30°·0] for the past seven years.

The highest recorded temperatures occurred on the 27th and 28th, and were as follows: Pittsburgh, 60°; Altoona, 56°; Chambersburg, 56°, and Aqueduct [Logania] 56°.

The lowest were on the 6th: Emporium, minus 26°; Saegerstown, minus 25°; Smethport, minus 24°; and Shingle House, minus 23°.

With the exception of 1885, this was the coldest February in the past twenty years. Not only were unusually low temperatures recorded on the 6th, but the month was uniformly cold. The navigation of the Delaware River was practically closed for days to shipping. By the assistance of the city ice boats the ferry boats were enabled to make irregular trips. Many persons crossed the river on the ice between Philadelphia and Camden.

From January 1, 1895, to February 28, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 302°; at Erie, 328°, and at Pittsburgh, 395°.

For the same period the deficiency in precipitation, in inches, at Philadelphia, was 0·69; Erie 2·09, and at Pittsburgh, 1·01.

NOTE—Crop correspondents are requested to resume their reports the first week in April. Blanks furnished on application.

When damage occurs by lightning, observers, crop correspondents, and others, are particularly requested to furnish this office with the following statistics, as soon thereafter as practicable, viz.:

Date, place, names of persons killed or injured, whether indoors or outdoors; stock, in stable or outside; barns with crops or without crops; dwellings, churches, etc. In each case state whether the buildings were with or without lightning rods, together with any other data of interest or scientific value. Newspaper clippings containing information of this nature requested. Special cards for report furnished on application.

TEMPERATURE.

	Mean Temperature.	Mean Precipitation, Inches.
February, 1888, ...	28°·4	2·50
1889, ...	23°·0	1·96
1890, ...	37°·1	4·32
1891, ...	34°·9	4·61
1892, ...	31°·7	1·75
1893, ...	27°·4	5·92
1894, ...	27°·6	3·53
1895, ...	20°·2	1·22

The means of the daily maximum and minimum temperatures, 29°·6 and 10°·8, respectively, give a monthly mean of 20°·2, which is 7°·4 below the corresponding month of 1894.

The average daily range was 18°·8.

Highest monthly mean, 25°·8 at *Philadelphia* [Centennial Avenue].

Lowest monthly mean, 13°·6 at Wellsboro.

Highest temperature recorded during the month, 60° on the 28th at Pittsburgh.

Lowest temperature, minus 26° on the 6th at Emporium.

Greatest local monthly range, 75° at Emporium.

Least local monthly range, 54° at South Bethlehem and Wilkes-Barre.

Greatest daily range, 55° at Saegerstown.

PRECIPITATION.

The average precipitation for the State, for the month, 1·22 inches, is 2·29 inches less than the average [3·51] for the past seven years.

General snows occurred on the 2d, 7th, 8th, 13th and 21st. Those of the 7th and 8th were heavy, and being accompanied by high winds and low temperatures, the snow drifted badly. Railroad trains were either completely blocked or much delayed, and many country roads rendered impassable for days.

Rain occurred on the 28th, and was the only rainstorm during the month.

The largest monthly totals of snowfall in inches were: Coatesville, 28·2; Blooming Grove, 26·0; Drifton, 25·8, and Kennett Square, 21·2.

But little remained on ground at the end of the month, and this was in patches, being the remains of the heavy drifts.

The largest monthly totals of rainfall and melted snow in inches were: Blooming Grove, 3·47; Coatesville, 2·93; Stoyestown, 2·60; Drifton, 2·58; Saegerstown, 2·38, and Wilkes-Barre, 2·32.

The least were: Altoona, 0·17; State College, 0·22; Huntingdon, 0·46; Davis Island Dam, 0·46; Elwood Junction, 0·47; Emporium, 0·50; and Towanda, 0·50.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 6; clear days, 10; fair days, 10; cloudy days, 8.

BAROMETER.

The mean pressure for the month, 30·07, is about ·03 below the normal. At the United States Weather Bureau Stations, the highest observed was 30·57 at Harrisburg on the 24th, and the lowest 29·30 at Philadelphia on the 7th.

MISCELLANEOUS PHENOMENA.

Snow.—Hamburg, 2d, 7th, 21st; Altoona, 1st, 8th, 21st, 28th; Hollidaysburg, 7th, 8th, 13th, 21st, 28th; Le Roy, 3d, 5th, 8th, 9th, 10th, 11th, 14th, 20th, 21st; Towanda, 7th, 8th, 13th; Quakertown, 2d, 4th, 8th, 13th, 21st, 23d; Cassandria, 2d, 4th, 8th, 13th, 21st, 23d; Emporium, 7th, 8th, 21st; East Mauch Chunk, 2d, 7th, 8th, 13th, 21st; State College, 2d, 7th; West Chester, 2d, 7th, 8th, 13th, 21st; Coatesville, 2d, 7th, 8th, 13th, 21st, 23d; Kennett Square, 2d, 4th, 7th, 8th, 13th, 21st; Phœnixville, 2d, 7th, 8th; Westtown, 2d, 7th, 8th, 21st; Grampian, 4th, 7th, 8th, 13th, 14th, 18th, 20th, 23d; Lock Haven, 7th, 8th, 13th, 21st; Saegerstown, 7th, 8th, 13th, 19th, 20th, 21st; Carlisle, 3d, 8th, 9th; Uniontown, 7th, 8th, 9th, 12th, 13th; Chambersburg, 7th, 8th, 13th; Huntingdon, 2d, 6th, 13th; Lancaster, 2d, 7th, 8th, 13th; Lebanon, 2d, 4th, 7th, 8th, 13th, 21st, 23d; Coopersburg, 2d, 7th, 8th, 13th, 21st, 23d; Drifton, 2d, 3d, 7th, 8th, 13th, 14th, 21st, 25th; Wilkes-Barre, 2d, 4th, 7th, 8th, 9th, 21st; Williamsport, 7th, 8th, 13th, 23d; Smethport, 8th, 9th, 21st; Greenville, 9th, 18th, 19th; Pottstown, 2d, 7th, 13th, 21st; South Bethlehem, 2d, 4th, 7th, 8th, 13th, 21st; Easton, 2d, 4th, 7th, 8th, 13th, 21st; Aqueduct, 2d, 7th, 13th, 21st; *Philadelphia* [Centennial Avenue], 2d, 4th, 7th, 8th, 13th, 21st, 23d; Blooming Grove, 2d, 7th, 8th, 9th, 13th, 21st; Shingle House, 8th, 9th, 24th; Selins Grove, 2d, 7th, 8th, 13th, 23d; Somerset, 6th, 7th, 8th, 9th, 13th, 21st; Wellsboro, 7th, 8th, 18th, 21st; Lewisburg, 7th, 8th, 21st, 23d; Dyberry, 2d, 4th, 7th, 8th, 21st; Honesdale, 2d, 4th, 7th, 8th, 13th, 21st; Salem Corners, 2d, 4th, 5th, 8th, 13th, 21st, 22d; South Eaton, 7th, 8th; York, 2d, 7th, 8th, 13th, 21st.

Aurora.—Le Roy, 14th, 15th, 23d; Saegerstown, 15th, 23d; Dyberry, 15th, 23d.

Solar Halo.—Le Roy, 12th, 27th; Towanda, 12th, 20th; South Bethlehem, 7th; *Philadelphia* [Weather Bureau], 1st, 3d, 6th, 12th; [Centennial Avenue], 1st, 6th, 12th, 19th, 27th; Wellsboro, 12th.

Lunar Halo.—Le Roy, 3d, 6th; Towanda, 3d, 6th; Emporium, 7th; West Chester, 1st, 6th; Phœnixville, 6th; Lebanon, 1st, 6th; *Philadelphia* [Weather Bureau], 1st, 3d, 6th, 12th; [Centennial Avenue], 1st, 3d, 6th; Wellsboro, 3d; Lewisburg, 6th.

PRECIPITATION DURING FEBRUARY, 1895.

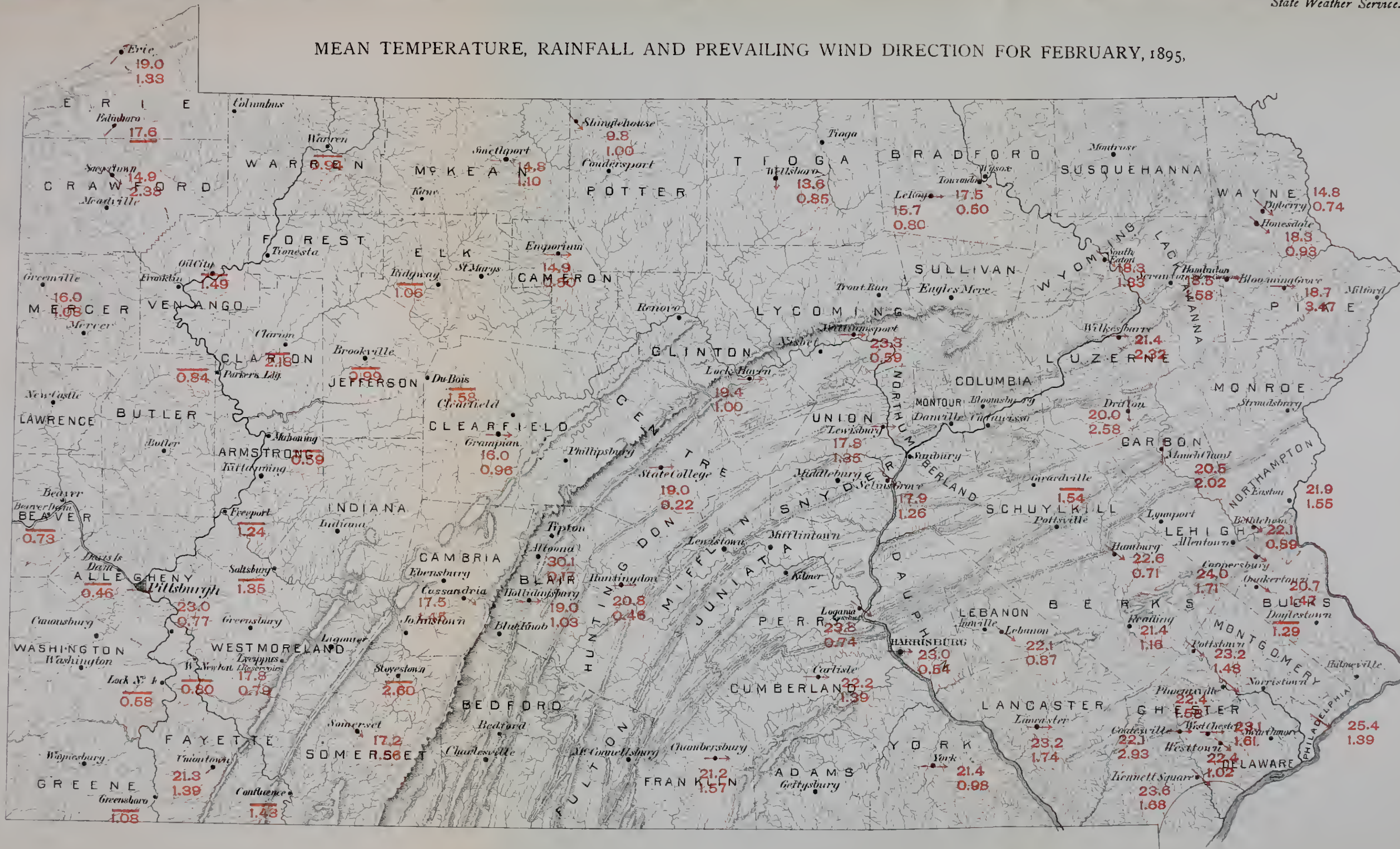
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin																																
Bethlehem,		·14					·65														·05							·05				0·89
Blooming Grove,		·10					‡	‡	2·00				·20	·81							·36											3·47
Browers Lock,		·26					·19	·39					·14								·02							·08				1·08
Coatesville,		·40					1·00	1·00					·20								·20		·02					·11				2·93
Coopersburg,		·16					·27	1·00					·10								·09		·01					·08				1·71
Doylestown,		·59		·09			·29	·14													·08		·04					·06				1·29
Dyberry,		·04		·04			·21	·40													·05											0·74
Easton,		·30		·10			‡	1·10					·03								·01							·01				1·55
Forks of Neshaminy,		·28		·01			·28						·05								·03							·09				0·74
Frederick,		·19		·02			·20	·2[illegible]					·03								·05							·16				0·88
Hamburg,		·09					·46														·16											0·71
Honesdale,		·06		·06			·40	·31					·03								·07											0·93
Kennett Square,		·30		·02			·40	·58					·15								·07							·16				1·68
Lansdale,		·58		·10			·17	·26													·10							·13				1·34
Mauch Chunk,		·13					·27	1·33					·07								·13							·09				2·02
Ottsville,		·20					·09	·52					·04								·03											0·88
Philadelphia, a†		·27					·30	·43					·10								·03							·26				1·39
Philadelphia, b,		·18					·34	·40					·09								·03							·24				1·28
Phœnixville,		·31		·03			·47	·45					·17								·04						·09	·02				1·58
Point Pleasant,		·23					·26	·18					·02															·04				0·73
Pottstown,		·25					1·00						·06								·05							·12				1·48
Quakertown,		·16		·05			‡	1·02					·03								·10		·02					·09				1·47
Reading,		·12		·01			·30	·48					·15								·06		·01					·03				1·16
(Salem Corners) Hamilnton,		·10		·08	·03		‡	·80					·05								‡	·48						·04				1·58
Seisholtzville,		·17					·90	·83					·11								·07							·10				2·18
Smith's Corner,		·25					·17	·20													·07							·08				0·77
Swarthmore,																																
West Chester,		·21					‡	1·00					·17								·05							·18				1·61
Westtown,		·20					‡	·40					·20								·07							·15				1·02
Susquehanna Basin.																																
Altoona,	·02							·08													·02							·05				0·17
(Aqueduct) Logania,		·09					·48						·09								·04						·01	·03				0·74
Carlisle,		*	·13					1·05	·10	·10																		·01				1·39
Drifton,		·10	·13				·35	1·40		*			·40	·05			*				·10	*		*	·05							2·58
Emporium,							·15	·15													·20											0·50
Girardville,		·12					·50	·40					·16	·08							·16	·12										1·54
Grampian,				·06			‡	·25					·14	·10				·09		·12			·06					·14				0·96
Harrisburg,†		·07					·11	·24					·02															·10				0·54
Hollidaysburg,							·34	·23					·21								·09							·16				1·03
Huntingdon,		·05				·30							·02															·09				0·46
Lancaster,		·17					‡	1·00					·19														‡	38				1·74
Lebanon,		·12		·01			·40	·09					·08								·03		·01					·13				0·87
Le Roy,			·03		·01			·20	·25	·05	·03			·10						·10	·03											0·80
Lewisburg,							·70	·40													·10		·10					·05				1·35
Lock Haven,							·40	·40					·10								·10											1·00
Selins Grove,		·20					·65	·25					·05								·06		·05									1·26
South Eaton,		·10					‡	1·00													·10	·05						·08				1·33
State College,		·03					·19																									0·22
Towanda,							‡	·40					·10																			0·50
Wellsboro,							‡	·65										·15			·05											0·85
Wilkes-Barre		·20		·15			·30	1·10	·36												·21											2·32
Williamsport,	*	*	*	*	*	*	·50	·04					·02										·03									0·59
York,		·15					·35	·16					·15								·02	·01						·14				0·98

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,		·02		·02			·08	·11	·03				·12								·02	·01	·01					·31				0·73
Brookville,					·02			·13	·22					·06	·02				·11		·18	·07	·05	·02				·11				0·99
Cassandria,		·05		·10			·30					·10									·30		·20					·40				1·45
Clarion,		·04	·02	·01	·01		·03	·16	·12	·07			·08	·07	·12				·18		·19	·34	·08	·01				·65				2·18
Confluence,		·10		·02	·10		·20	·30	·09				·18	·01	·02							·09		·02				·30				1·43
Davis Island Dam,							·06	·03	·01				·02									·02						·32				0·46
DuBois,							·07	·27	·17				·19		·05				·16		·21	·10	·06					·30				1·58
Elwood Junction,									·01													·11						·35				0·47
Freeport,		·04					·07	·22	·15	·05			·09		04					·02	·06							·50				1·24
Greensboro,		·07		·02	·01		·20	·20	·04				·14	·02	·03						·06	·03		·02				·24				1·08
Greenville,									·50									·10	·03									·45				1·08
(Immel Reservoir) Lycippus,		·05					·17			·21			·26															·10				0·79
Johnstown,		·01		·01	·01		·06	·18	·01				·04	·10	·01						·02	·13						·40				0·98
Lock No. 4,		·02					·10	·20	·05				·05															·16				0·58
Mahoning,		·02		·01				·10	·06	·02			·05								·03							·30				0·59
Oil City,				·05	·03		·01	·15	·14	·05		·03	·04	·03	·03			·07	·05	·02	·15	·08	·04					·52				1·49
Parker's Landing,		·01		·02	·02		·01	·02	·12	·05			·01		·01				·15		·10	·06	·02					·24				0·84
Pittsburg,†		·01		·01		·05	·19	·08				·06	·04								·03						·02	·28				0·77
Ridgway,		·02						·15		·30				·10					·03		·20	·04	·01					·21				1·06
Saegerstown,								·60	·55				·05						·08	·30	·35							·45				2·38
Saltsburg,		·02		·02	·03		·11	·32	·02	·05			·12	·03	·01						·03	·08	·01					·50				1·35
Shingle House,								·20	·40															·40								1·00
Smethport,								‡	·40												·50							·20				1·10
Somerset,						·10	·42	·10	·11				·34								·21							·28				1·56
Stoyestown,			·12	·15	·20	·30	·20	·40		·10		·10	·20	·20							·05	·23	·06					·29				2·60
Uniontown,			·12	·40	·15	·12			·15	·10																		·35				1·39
Warren,				·01	·01			·09	·20				·10	·10					·09	·01	·19	·01	·10					·03				0·94
West Newton,		·02					·09	·21					·08									·05						·35				0·80
Potomac Basin.																																
Chambersburg,		·01					·70	·80					·05															·01				1·57
Lake Basin.																																
Erie,†	·03	·01		·13			·14	·21	·09				·06					·06			·18		·15				·14	·13				1·33

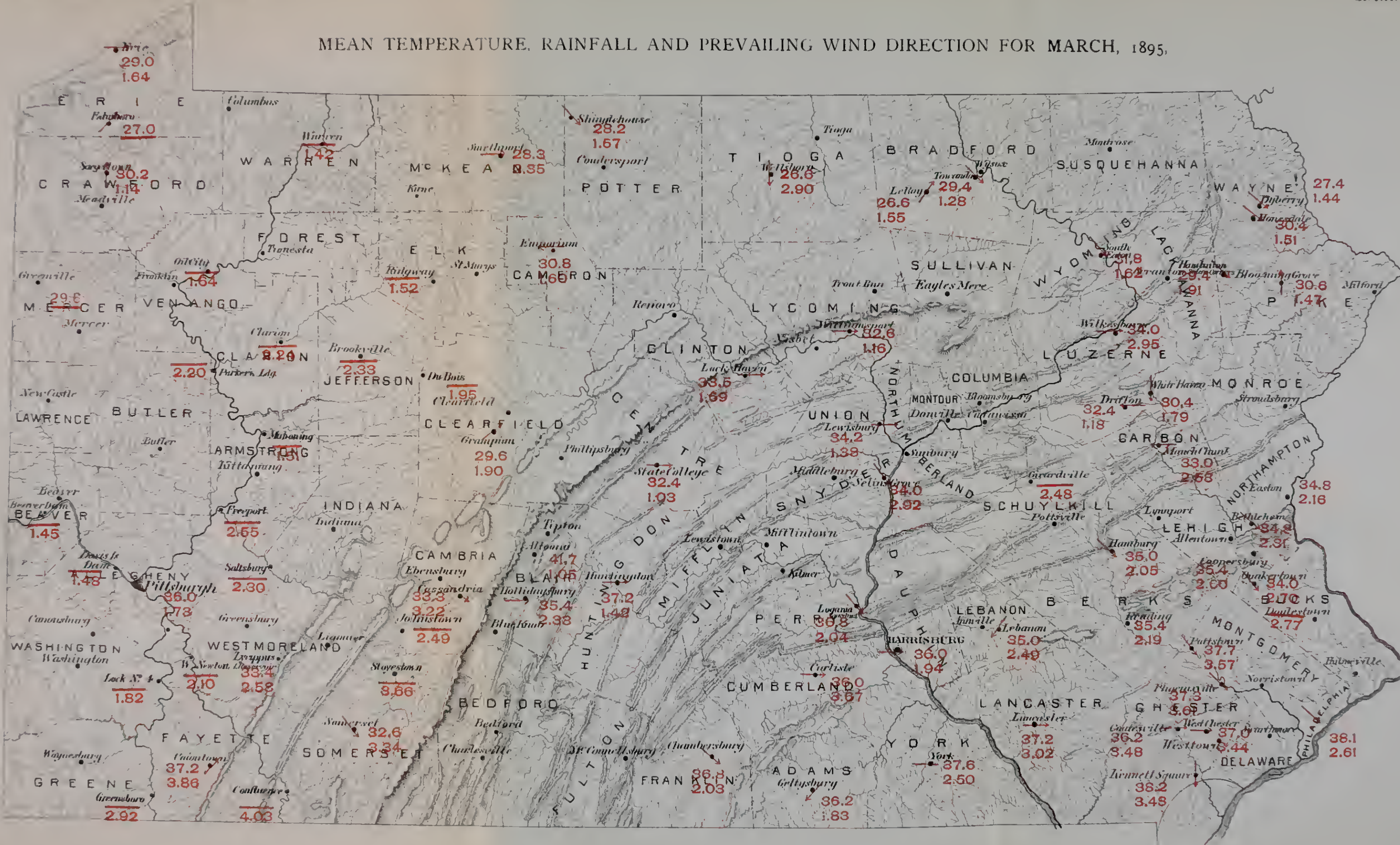
†U. S. Weather Bureau Stations. * Missing. ‡ Amount included in measurement following.

4	5	6	7	8	
·02	. .	. .	·08	·11	.
. .	·02	. .	. .	·13	.
·10	. .	. .	·30	.	.
·01	·01	. .	·03	·16	.
·02	·10	. .	·20	·30	.
. .	. .	. .	·06	·03	.
. .	. .	. .	·07	·27	.
. .	. .	. .	.	. .	.
. .	. .	. .	·07	·22	.
·02	·01	. .	·20	·20	
. .	. .	. .	. .	. .	
. .	. .	. .	·17	. .	
·01	·01	. .	·06	·18	
	. .	. .	·10	·20	
·01	. .	. .	. .	·10	
·05	·03	. .	·01	·15	
·02	·02	. .	·01	·02	
·01	. .	·05	·19	·08	
. .	. .	. .	. .	·15	
. .	. .	. .	. .	·60	
·02	·03	. .	·11	·32	
. .	. .	. .	. .	·20	
. .	. .	. .	. .	‡	
. .	. .	·10	·42	·10	
·15	·20	·30	·20	·40	
·40	·15	·12	. .	. .	
·01	·01	. .	. .	·09	
. .	. .	. .	·09	·21	
. .	. .	. .	·70	·80	
·13	. .	. .	·14	·21	

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR FEBRUARY, 1895.



MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR MARCH, 1895.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR MARCH, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 31, 1895.

GENERAL REVIEW.

The average temperature for March, 1895, 33°·8, is 1°·5 below the average [35°·3] for the past seven years.

The highest recorded temperatures occurred on the 1st, 24th, 25th and 31st, and were as follows: Coatesville, 70°; Uniontown, 68°; Lancaster, 67°; Pottstown, 67°, and Lycippus, 67°.

The lowest were on the 3d, 5th, 14th and 15th: Wellsboro, minus 4°; Smethport, 1°; Shingle House, 1°; and Edinboro, 1°.

At the close of the month, grain and grass appear to have wintered well, but all vegetation is backward, with but few signs of spring.

From January 1, 1895, to March 31, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 328°; at Erie, 419°, and at Pittsburgh, 483°.

For the same period the deficiency in precipitation, in inches, at Philadelphia, was 1·23; Erie 3·40, and at Pittsburgh, 3·08.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
March, 1888, ...	31°·1	3·55
1889, ...	38°·9	2·90
1890, ...	33°·4	5·15
1891, ...	34°·1	5·10
1892, ...	32°·0	4·14
1893, ...	34°·7	2·52
1894, ...	43°·2	1·63
1895, ...	33°·8	2·31

The means of the daily maximum and minimum temperatures, 42°·9 and 24°·8, respectively, give a monthly mean of 33°·8, which is 9°·4 below the corresponding month of 1894.

The average daily range was 18°·1.

Highest monthly mean, 39°·3 at *Philadelphia* [Centennial Avenue].

Lowest monthly mean, 26°·6 at Le Roy and Wellsboro.

Highest temperature recorded during the month, 70° on the 1st at Coatesville.

Lowest temperature, minus 4° on the 3d at Wellsboro.

Greatest local monthly range, 63° at Shingle House.

Least local monthly range, 40° at South Bethlehem.

Greatest daily range, 55° at Drifton.

PRECIPITATION.

The average precipitation for the State, for the month, 2·31 inches, is 1·26 inches less than the average [3·57] for the past seven years.

General snows occurred on the 2d, 9th, 11th, 12th, 15th and 16th, but they were mostly light and without drift. Most of the snow remaining on ground at the end of the month, was the remains of the heavy drifts in February.

The heaviest snowfall totals in inches for the month were: Cassandria, 22·0; Somerset, 20·5; Wellsboro, 18·0, and Salem Corners, 12·6.

The largest totals of rainfall and melted snow in inches were: Confluence, 4·03; Uniontown, 3·86; Carlisle, 3·67; Stoyestown, 3·66; Phœnixville, 3·61; Pottstown, 3·57, and Forks of Neshaminy, 3·51.

The least were: Elwood Junction, 0·99; State College, 1·03; Altoona, 1·05; Saegerstown, 1·14; Williamsport, 1·16, and Towanda, 1·28.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 11; clear days, 10; fair days, 10; cloudy days, 11.

BAROMETER.

The mean pressure for the month, 30·04, is about ·02 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·65 at Harrisburg on the 23d, and the lowest 29·44 at Erie on the 1st.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—Hollidaysburg, 25th, 26th; Le Roy, 25th; Towanda, 25th; Quakertown, 25th; Cassandria, 25th, 27th; Emporium, 25th; East Mauch Chunk, 25th; State College, 27th; West Chester, 25th; Coatesville, 25th; Kennett Square, 25th; Phœnixville, 25th; Lock Haven, 25th, 27th; Uniontown, 27th; Huntingdon, 25th; Coopersburg, 25th; Williamsport, 8th, 25th, 31st; Smethport, 25th; Pottstown, 25th; South Bethlehem, 25th; Easton, 25th; Logania, 9th, 25th; Selins Grove, 9th, 25th, 27th, 28th; Somerset, 25th, 27th; Wellsboro, 25th; Lewisburg, 24th, 28th, 31st; Dyberry, 25th; Hamlinton, 25th; South Eaton, 25th.

Hail.—Gettysburg, 15th; Towanda, 30th; Kennett Square, 9th, 15th; Phœnixville, 14th, 15th; Wilkes-Barre, 30th; South Bethlehem, 15th; Logania, 25th; Blooming Grove, 30th; Selins Grove, 28th; Dyberry, 13th, 15th; Honesdale, 30th; Hamlinton, 15th; York, 15th.

Snow.—Gettysburg, 2d, 11th, 15th, 16th; Hamburg, 2d, 9th, 11th, 12th; Hollidaysburg, 2d, 11th, 12th, 15th, 16th, 18th, 24th; Le Roy, 2d, 4th, 6th, 9th, 15th, 26th, 27th; Towanda, 2d, 6th, 15th, 26th; Quakertown, 2d, 15th, 16th; Cassandria, 2d, 6th, 9th, 12th, 14th, 15th, 16th, 17th, 18th, 26th; Emporium, 2d, 4th, 6th, 7th, 9th, 15th, 16th, 24th; East Mauch Chunk, 3d, 9th, 12th, 15th, 16th; State College, 2d, 9th, 15th, 16th, 18th, 24th; West Chester, 11th; Coatesville, 2d, 9th, 11th, 15th, 16th; Kennett Square, 1st, 11th, 15th; Phœnixville, 2d, 11th, 15th; Grampian, 2d, 4th, 6th, 7th, 9th, 12th, 15th, 16th, 24th; Lock Haven, 2d, 6th, 9th, 13th, 14th, 15th, 16th, 24th; Carlisle, 11th, 15th, 16th, 24th; Uniontown, 2d, 8th, 16th; Huntingdon, 2d, 11th, 15th, 24th; Lancaster, 2d, 11th, 12th, 13th, 14th, 15th, 16th; Lebanon, 2d, 9th, 11th, 12th, 15th, 16th, 24th; Coopersburg, 2d, 9th, 15th, 16th; White Haven, 2d, 7th, 9th, 28th; Wilkes-Barre, 2d, 9th, 12th, 15th; Williamsport, 2d, 6th, 8th, 16th; Smethport, 4th, 6th, 7th, 16th, 24th, 26th; Pottstown, 2d, 9th, 11th, 14th, 15th; South Bethlehem, 2d, 9th, 12th, 15th, 16th; Easton, 2d, 9th, 16th; Logania, 2d, 9th, 11th, 14th, 15th, 24th; *Philadelphia* [Centennial Avenue], 2d, 9th, 11th, 15th, 26th; Blooming Grove, 2d, 6th; Shingle House, 4th, 6th, 7th, 15th, 24th, 25th, 26th, 27th; Selins Grove, 2d, 9th, 12th, 15th, 16th; Somerset, 2d, 8th, 10th, 14th, 15th, 17th, 18th, 24th, 26th; Wellsboro, 2d, 4th, 6th, 9th, 11th, 15th; Lewisburg, 2d, 9th, 11th, 15th, 16th, 24th; Dyberry, 2d, 4th, 6th, 12th, 13th, 15th, 26th, 28th; Honesdale, 2d, 6th, 12th, 15th, 26th; Hamlinton, 2d, 4th, 6th, 9th, 12th, 15th, 16th, 24th, 26th; Lycippus, 2d, 8th, 9th, 15th, 18th, 27th; South Eaton, 2d, 9th, 15th; York, 2d, 9th, 11th, 15th, 16th, 24th, 26th.

Sleet.—Gettysburg, 15th, 24th; Hollidaysburg, 15th; Towanda, 30th; Quakertown, 2d, 15th, 30th; Coatesville, 15th; Kennett Square, 12th, 15th; Lock Haven, 4th; Huntingdon, 15th; Lancaster, 15th; Lebanon, 25th; Coopersburg, 15th; White Haven, 15th; Easton, 15th; Logania, 9th, 14th, 15th, 29th; *Philadelphia* [Centennial Avenue], 2d, 15th, 29th; Selins Grove, 15th; Dyberry, 13th, 15th; Honesdale, 12th, 13th.

Coronæ.—Towanda, 3d, 8th.

Solar Halo.—Philadelphia [Weather Bureau], 27th; [Centennial Avenue], 21st, 24th, 27th; Wellsboro, 20th.

Lunar Halo.—Towanda, 3d.

Parhelias.—Le Roy, 31st; Towanda, 11th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for March, 1895.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for April, 1895.

County.	Station.	Elevation above Sea Level (feet).	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers.
Adams,	Gettysburg,		49·8	85	25	28	18	60·6	38·9	21·7	43	3·27	...	...	10	11	12	7	NE	H. F. Buehler.
Allegheny,	Pittsburgh,	820	54·0	82	25	28	3	63·0	45·0	18·0	33	1·83	0·2	...	10	7	11	12	N	O. D. Stewart, W. B
Berks,	Hamburg,	380	49·8	86	25	25	4	59·8	39·8	20·0	42	6·85	...	...	9	5	14	11	E	William Shipe.
Berks,	Reading,[2]	280	50·0	...	...	...	...	...	...	...	...	4·28	...	...	12	...	...	...	...	Franklin Yager.
Blair,	Altoona,	1,181	54·5	84	27	30	11	63·3	45·7	17·6	29	2·16	...	...	9	...	...	...	...	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	49·7	86	25	22	11	62·7	36·7	26·0	47	2·52	...	...	8	15	3	12	E	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	44·8	76	25	20	11	53·9	35·7	18·2	35	2·65	0·2	...	13	8	3	19	SW	G. W. T. Warburton
Bradford,	Towanda,	754	46·8	80	25	25	11	56·5	37·2	19·3	43	1·70	T	...	11	7	8	15	NW	Hiram E. Bull.
Bucks,	Forks of Neshaminy,[1]	304	52·1	...	...	...	...	...	...	...	...	6·04	...	...	12	16	...	14	N	J. C. Hilsman.
Bucks,	Quakertown,	536	47·9	84	25	25	5	58·7	37·1	21·6	40	5·41	T	...	13	5	10	15	NE	J. L. Heacock.
Cambria,	Cassandria	2,100	49·2	83	26	24	3	56·1	42·3	13·8	32	3·61	T	...	13	11	7	12	SE	A. H. Boyle.
Cambria,	Johnstown,	1,184	52·0	85	26	25	11	64·3	39·7	24·6	43	4·38	...	...	12	15	9	6	S	E. C. Lorentz.
Cameron,	Emporium,	1,050	49·1	82	26	20	11	60·0	38·2	21·8	48	2·53	T	...	8	9	10	11	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	48·6	84	25	23	4	58·8	38·4	20·4	43	6·32	...	...	10	14	5	11	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	48·4	80	25	23	11	56·5	40·2	16·3	41	2·23	T	...	8	9	4	17	E	Prof. Wm. Frear.
Chester,	West Chester,	455	50·0	84	25	29	4, 11	58·8	41·1	17·7	30	5·37	...	...	11	14	3	13	NW	J. C. Green, D.D.S.
Chester,	Coatesville,	380	49·8	87	25	25	4, 12	61·2	38·5	22·7	43	4·63	...	...	11	14	8	8	NE	W. T. Gordon.
Chester	Kennett Square,	275	50·2	85	25	26	4	61·3	39·1	22·2	38	5·74	...	...	12	10	5	15	S	B. P. Kirk.
Chester,	Phœnixville (29 days),	190	50·5	85	25	30	4	60·1	40·9	19·2	34	5·19	...	...	10	7	6	17	NW	T. Knowles Perot.
Chester,	Westtown,‡	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	John D. Carter.
Clearfield,	Grampian,	1,450	47·2	84	26	20	11	56·5	37·9	18·6	42	3·81	0·5	...	11	4	14	12	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	50·8	88	25	§28	11	...	...	...	...	0·79	...	...	7	13	2	15	W	Prof. J. A. Robb.
Crawford,	Saegerstown,	1,200	47·2	80	30	17	11	60·3	34·0	26·3	49	1·40	T	...	10	8	10	12	NW	J. G. Apple.
Cumberland,	Carlisle,	480	51·0	87	25	28	18	61·2	40·9	20·3	44	3·75	...	...	10	14	5	11	SE	J. E. Pague.
Dauphin,	Harrisburg,	480	50·5	84	25	31	11	59·0	42·0	17·0	34	3·67	...	...	10	10	6	14	E	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College‡,	361	...	...	...	...	...	...	...	...	...	5·53	...	...	...	...	...	...	...	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	46·6	75	21	19	11	...	...	...	...	...	...	...	...	...	...	...	W	C. F. Sweet.
Erie,	Erie,	1,400	45·0	76	24	23	1	54·0	36·0	18·0	38	2·09	...	...	10	9	12	9	NE	P. Wood, W. B.
Fayette,	Uniontown,	681	51·4	80	26	27	3	61·2	41·5	19·7	38	4·12	T	...	11	9	11	10	NW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	48·9	82	26	26	4	60·9	36·9	24·0	42	2·95	...	...	9	10	10	10	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	50·2	86	26	25	4, 11	63·3	37·1	26·2	48	1·97	...	...	6	1	18	11	W	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	50·3	83	25	28	11	61·7	38·9	22·8	37	5·07	...	...	13	10	9	11	E	A. V. Heister
Lebanon,	Lebanon,	458	51·9	85	25	27	11	‖63·2	38·6	24·6	42	5·10	...	...	11	12	5	13	NE	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	49·4	83	25	28	5, 12	59·2	39·7	19·5	36	5·40	0·3	...	11	13	5	12	NW	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	47·2	80	25	20	2	61·0	33·4	27·6	49	4·24	2·5	...	10	10	4	12	N	J. R. Wagner.
Luzerne,	White Haven,		45·2	81	25	21	5	54·5	35·8	18·7	36	4·24	...	...	11	5	12	13	N	C. M. Driggs.
Luzerne,	Wilkes-Barre,	575	49·9	85	25	26	5, 11	62·7	37·1	25·6	44	2·71	...	...	7	10	5	15	W	A. W. Betterly.
Lycoming,	Williamsport,		50·0	82	25	29	3, 11	59·0	41·1	17·9	39	2·17	...	...	10	12	8	10	E	G. D. Snyder, C. E.
McKean,	Smethport,	1,500	46·0	76	25	18	11	57·2	34·8	22·4	48	2·46	1·0	...	9	8	12	10	SE	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	47·4	80	26	20	11	58·3	36·5	21·8	40	2·35	...	...	6	20	2	8	...	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	51·7	87	25	30	4	61·5	41·9	19·6	40	5·13	...	...	8	15	7	8	NE	Charles Moore, D.D.S.
Northampton,	South Bethlehem,	339	49·2	84	25	28	5	59·0	39·5	19·5	37	...	...	...	...	10	6	14	NW	T. Merriman.
Northampton,	Easton— Lafayette College,	325	49·6	81	25	29	4, 11	59·4	39·7	19·7	35	3·91	...	...	11	13	4	13	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	51·4	90	25	28	4	62·2	40·6	21·6	45	4·23	...	...	13	11	8	11	SE	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	51·6	84	25	32	11	60·2	43·1	17·1	31	6·14	...	...	11	11	3	16	NE	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	52·1	84	25	31	11	61·0	43·2	17·8	30	5·59	...	...	11	11	5	14	NE	John Comly.
Pike,	Blooming Grove,*[1]	...	45·8	78	26	24	4	...	...	...	...	5·21	2·5	...	11	2	14	14	W	John Grathwohl.
Potter,	Shingle House,	1,475	45·8	78	26	5	4	59·2	32·5	26·7	45	1·81	...	...	6	11	3	16	N	H. L. Pearsall.
Snyder,	Selins Grove,	455	49·2	85	23	26	4, 11	63·0	35·3	27·7	48	2·55	...	...	8	...	22	8	NW	J. M. Boyer.
Somerset,	Somerset,	2,250	47·8	80	25	20	10	60·8	34·9	25·9	42	2·58	...	...	5	4	18	8	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	42·7	74	25	20	5	...	...	...	...	2·21	...	...	7	8	5	17	S	H. D. Deming
Union,	Lewisburg	450	49·6	86	25	25	5	61·3	37·9	23·4	43	2·41	...	...	8	9	5	16	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	44·4	79	26	18	4	54·4	34·3	20·1	43	3·22	1·5	...	13	11	4	15	NW	Theodore Day.
Wayne,	Honesdale,	1,000	45·8	77	25	24	4, 11	54·9	36·6	18·3	37	3·39	1·8	...	12	9	9	12	E	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,†	1,600	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	51·8	85	27	23	3, 4	59·8	43·7	16·1	28	4·46	...	...	8	...	...	...	...	Murray Forbes.
Wyoming,	South Eaton,	660	47·4	81	25	25	4, 5	57·7	37·2	20·5	39	3·60	...	...	9	9	6	15	NW	B. M. Hall.
York,	York,	385	50·0	84	25	28	4, 18	60·8	39·2	21·0	40	3·73	T	...	10	14	5	11	W	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 2.
† No records. ‡ Records incomplete. § Observed reading. ‖ 19 days.

5	6	7	8	9	10	11
·08	·06	·09	·17	·14	. .	. .
·05	·12	·14	. .	·22	. .	. .
. .	·05	·09	. .	·20	. .	. .
·05	·05	·10	·21	·18	. .	. .
·20	. .	.	·10	·18	. .	
·11	·02	·08	·23	·12	. .	. .
·12	·10	·21	·18	·21	.	. .
·06	. .	·06	·06	·03	. .	. .
·13	. .	·15	·22	·20	. .	. .
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·09	. .	. .	·25	·13	. .	. .
·09	·01	·04	·09	·22	.	. .
. .	·01	. .	·22	·18	. .	. .
·01	·02	·13	·21	·16	. .	.
·11	·03	·08	·09	·08	. .	. .
·16	·11	·11	·08	·06	. .	. .
. .	·06	·23	·02	·14	. .	. .
·20	·01	·10	·08	·20	. .	. .
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·05	·09	·05	·09	. .	. .	·04
. .	·12	·19	·47	. .	. .	·08
·30	. .	·01	·02	·09	. .	. .
. .	. .	. .	·26	·25	. .	.
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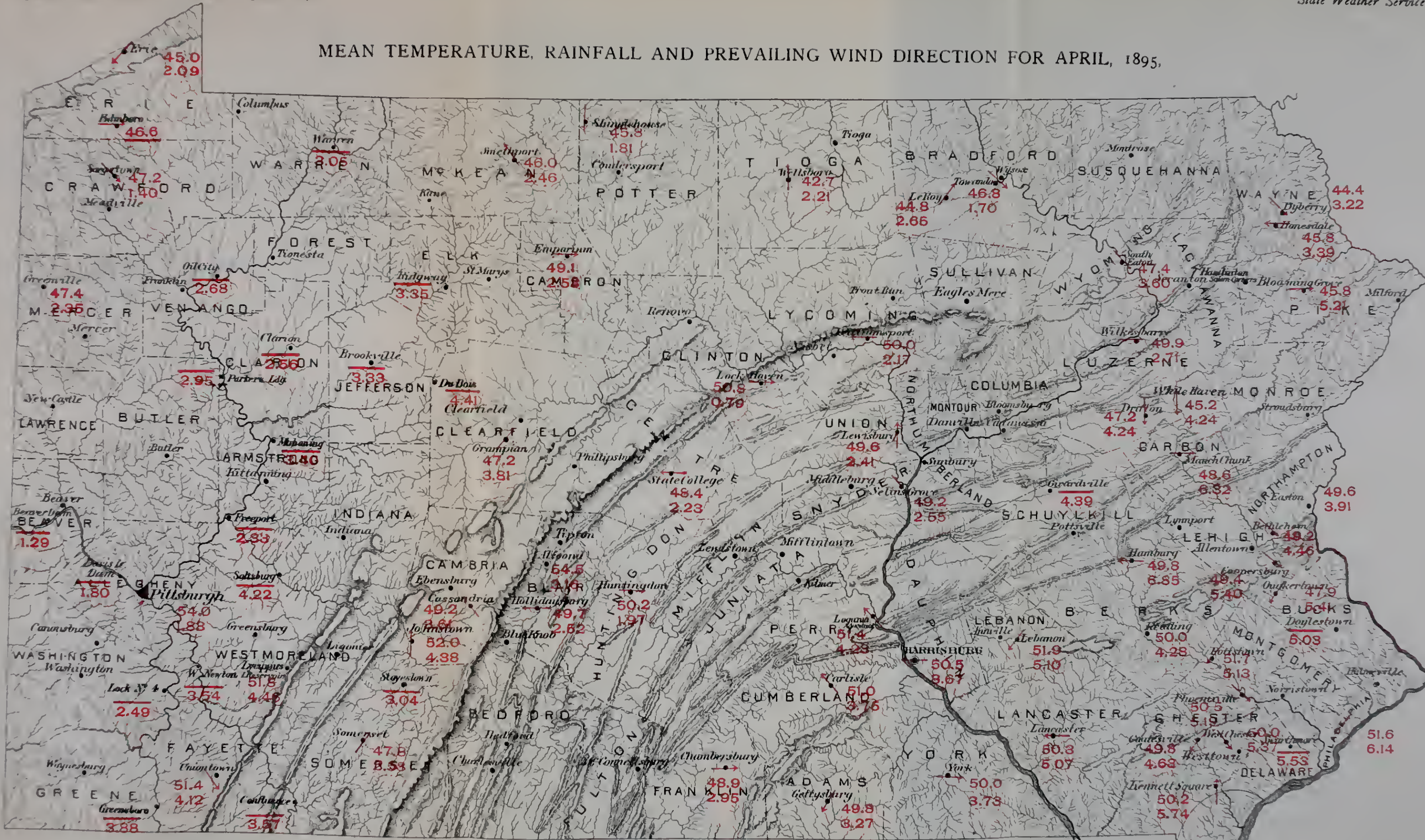
. .	. .	. .	·04	·06	. .	. .

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Bethlehem,		'43						‡	2'24				'78									'07					'56		‡	'38		4'46
Blooming Grove,	'24	'17				'03	‡	‡	‡	3'10			1'20									'15					'27			'05		5'21
Browers Lock,		'23	'33					1'52	'55				'54									'13					'58	'59	'27	'20		4'94
Coatesville,	'10	'45						1'81	'06	'02			'77									'10					'70	'21	'28	'13		4'63
Coopersburg,	'04	'30	'08					1'86	'84				1'24									'08					'53	'10	'17	'10		5'40
Doylestown,	'06	'42						2'23	'61				'75									'06					'50	'07	'27	'06		5'03
Dyberry,	'09	'17	'05			'08	'02	'88	1'00				'44									'02			'03		'34		'01	'09		3'22
Easton,	‡	'54							2'28	'01			‡	'42								'01					‡	'55	‡	'10		3'91
Forks of Neshaminy,	'07	'33	'11					2'54	95	'10			'61									'10					'04	'14	'24	'20		6'04
Frederick,	'05	'59	'08					1'84	'65	'02			'72									'06					'14	'18	'20	'22		5'15
Hamburg,	40	[illegible]						2'00	'28				1'50									'31					1'02		26	'18		6'85
Honesdale,	'19	'13	'03			'05		'78	1'05				'71									'10			'02		'20		'03	'10		3'39
Kennett Square,	'14	'30	'13					2'05	'44				'80	'02								'08					'56	'55	'37	'30		5'74
Lansdale,	'05	41						1'55	'72				'65									'07					'75	'08	'24	'06		4'88
Mauch Chunk,		'19	'15					1'44	1'72	'02			1'75									'21					'33		'09	'42		6'32
Ottsville,	'04	'30						1'69	'89				1'15									'05					'55		'16	'16		4'99
Philadelphia, a†	'11	'15	'17					2'18	1'11				'49									'07					'64	'36	'52	'31		6'14
Philadelphia, b.	'11	'22	'14					2'21	'78				'51									'08					'55	'25	'48	'26		5'59
Phoenixville,	'06	'63						1'77	'42				'75									'10					68	'42	'22	'14		5'19
Point Pleasant,		'25						2'88	'86				1'03														'43	'21	'11	'19		5'09
Pottstown,	'35	'33						2'05					'85									'05					1'00		'35	'15		5'13
Quakertown,	'06	'28	'27					1'47	1'00	'05			1'31	'03								'07					'36	'07	'24	'20		5'41
Reading,	'01	'40	'26					1'49	'13	'01			1'00									'01					'90	'05	'15	'07		4'28
(Salem Corners) Hamlinton,																																
Seisholtzville,	45	'08	'13					3'11	'97				1'15									'08					'56	'12	'17	'27		7'09
Smith's Corner,	09	44	'04					2'00	'75				1'12									'06					'42	'15	'26	'27		5'60
Swarthmore,	'02							‡	3'00				'55									'01					‡	‡	1'95			5'53
West Chester,	'10	'41	'02					2'19	'21				'88									'11					'58	'26	'34	'27		5'37
Westtown,																																
White Haven,	'09	'13	'03					1'85	'36	'05			1'14									'16					'19		'08	'16		4'24
Susquehanna Basin.																																
Altoona,			'05					'24	'26				1'27	'13								'05					'03	'11		'02		2'16
(Aqueduct) Logania,		'30	'01					'83	1'27	'07			'20	'01	'01							'03					1'20	'03	'07	'20		4'23
Carlisle,		'02	'22				‡	1'10	'40				'24														1'10	'36	'18	'13		3'75
Drifton,		'25					*	1'55	'67		'37	'55	'13	*							*	'16					'13	*	'10	'33		4'24
Emporium,	'19	'06					'18	'33	'67				'88									'10					'12					2'53
Gettysburg,		'42	'11					'52	'44				'25									'06					'80	'25	'15	'27		3'27
Girardville,		'42						1'40	'52				1'11									'16								'78		4'39
Grampian,	'22	'06					'23	'25	1'00			‡	1'65									'10	'04			'02				'24		3'81
Harrisburg,†		'24	'03					'90	'69				'46									'06					'82	'22	'10	'15		3'67
Hollidaysburg,		'14					'14	'30	'21				1'18									'06					'34			'15		2'52
Huntingdon,		'14					‡	'45				‡	'93														'45					1'97
Lancaster,		‡	‡	'64			‡	‡	1'76			‡	'54									'08					‡	‡	‡	2'05		5'07
Lebanon,	'08	'35	'02					1'42	'16				1'02									'14					1'42	10	'13	'26		5'10
Le Roy,	'14	'04	'02			'04		'46	'90	'12			'54		'08							'05			'06		'18			'02		2'65
Lewisburg,		'10						'80	'60				'45	'02								'06					'35		'03			2'41
Lock Haven,	'03								'05			'02	'54									'05					'04			'06		0'79
Selins Grove,	'02	'14	'02					'79	'53				'40													'12	'53					2'55
South Easton,	'25		'08					'75	1'22	'04			'63									'14			'04		'45					3'60
State College,		'09					'02	'42	'19				'98									'08					'17			'28		4'23
Towanda,	'12	'01				'05		'23	'65				'36		'02							'01			'07		'16			'02		1'70
Wellsboro,	'16							'65	'25			'12	'78													'05	'20					2'21
Wilkes-Barre								'64	'45				'99									'02					'53		‡	'08		2'71
Williamsport	'10	'02						'58	'37	'10			'68									'09				‡	'20			'03		2'17
York,		'41	'16					1'12	'25				'30									'07					'75	'30	'25	'12		3'73
Ohio Basin.																																
Beaver Dam,	'08	'07	'03					'20	'08	'22			'54	'01	'01							'05										1'29
Brookville,	'04	'07	'03					'41	1'39	'32			'92	'04		'03						'06	'02									3'33
Cassandria,	'05	'08					‡	'56	'67				1'73	'11								'13	'01				'24		'02	'01		3'61
Clarion,	'05	'09	'04					'26	'62	'12			1'21									'07	'05				'05					[illegible]
Confluence,	'01	'45	'23	'02				'30	'61	'81			'84	'10	'03	'04											'02	'03		'06		3'57
Davis Island Dam,	'12	'07	'05					'20	'30	'21			'60	'03	'01							'16	'05									1'80
DuBois,	09	'30	'15					'45	1'70	'28			'95	'35		'05						'07	'02									4'41
Elwood Junction,	'01	'08			'01		'09		'15	'33			'25	'07								'04	'02									1'56
Freeport,	'08	'10	'14					'25	'72	'15			'73	'06	'02							'04	'04									2'33
Greensboro,	'03	'45	'30					'40	'45	'45			'85	'26	'32	'08							'24					'05				3'88
Greenville,	'20						'68		'16			'88	'30										'13									2'35
(Immel Reservoir) Lycippus,		'12	'15					'29	1'20	'58			1'68									'32					'12					4'46
Johnstown,	'08		'08				'25	'61	'53	'83			1'58		'12							'15	01				'12		'02			4'38
Lock No. 4,	'02	'07	'14					'22	'29	23			1'17	'03	'02							'12	'13				'01	'03	'01			2'49
Mahoning,	'05	'08	'06					'34	'86	'24			1'58	'11								'05	'02				'01					3'40
Oil City,	'12	'09						'12	'72	'19			1'06	'21		'03						'05	'09									2'68
Parker's Landing,	'01	'15						'52	'72	'16	'02		1'18	'06								'05	'07				'01					2'95
Pittsburg,†	'12	'15			'01		'08	'17	'40			'26	'40									'22	'02									1'83
Ridgway,	'11	'06	'05					'46	1'63	'12			'78	'04		'02	'01					'07										3'35
Saegerstown,	'18	'01					'08	'02	'11			'35	'15		'10								'34				'06					1'40
Saltsburg,	'04	'09	'17	'02	'03			'40	1'18	'43			1'19	36								'07	'20							'04		4'22
Shingle House,	'35						'10	'25	'75				'35									'01										1'81
Smethport,	'30	'10					‡	'38	'98			‡	'50		'05								'15									2'46
Somerset,							'25	'15	1'25	'78																		'15				2'58
Stoyestown,		'18	'32					'35	'75	'18			'77	'18			'03						'09					'16		'03		3'04
Uniontown,	'38	'28					'20	'36	'87			'17	1'14	'32	'05							'28					'07					4'12
Warren,	'05	'31	'01					'03	1'17	'50			'56			'15						'27										3'05
West Newton,		'10	'13					'30	'47	'52			1'50	'10	'13								'25					'04				3'54
Potomac Basin.																																
Chambersburg,		'30					'01	'85	'25				'25														'70	'20	'15	'24		2'95
Lake Basin.																																
Erie,†	'24					'02	'02	'04	1'06			'22	'03		'04							'40	'02									2'09

† U. S. Weather Bureau Stations. * Missing. ‡ Amount included in measurement following.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR APRIL, 1895.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR APRIL, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 30, 1895.

GENERAL REVIEW.

The average temperature for April, 1895, 49°·2, is 1°·2 above the average [48°·0] for the past seven years.

The highest recorded temperatures occurred on the 25th and were as follows: Aqueduct, Logania, 90°; Lock Haven, 88°; Carlisle, 87°; Coatesville, 87°; and Pottstown, 87°.

The lowest were on the 4th and 11th: Shingle House, 5°; Saegerstown, 17°; Dyberry, 18°; and Smethport, 18°.

At the close of the month, grain and grass were in good condition, but had made slow growth and all vegetation continued unusually late and backward.

From January 1, 1895, to April 30, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 298°; at Erie, 422°, and at Pittsburgh, 399°.

For the same period the excess in precipitation, in inches, at Philadelphia, was 2·05; and deficiency at Erie 3·96, and at Pittsburgh, 3·09.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
April, 1888	46°·5	2·52
1889	48°·7	4·50
1890	48°·7	3·46
1891	49°·8	2·08
1892	47°·0	2·04
1893	47°·6	4·74
1894	48°·0	3·62
1895	49°·2	3·76

The means of the daily maximum and minimum temperatures, 59°·8 and 38°·7, respectively, give a monthly mean of 49°·2, which is 1°·2 above the corresponding month of 1894.

The average daily range was 21°·1.

Highest monthly mean, 54°·0 at Pittsburgh.

Lowest monthly mean, 42°·7 at Wellsboro.

Highest temperature recorded during the month, 90° on the 25th at Aqueduct, Logania.

Lowest temperature, 5° on the 4th at Shingle House.

Greatest local monthly range, 73° at Shingle House.

Least local monthly range, 52° at Easton and Philadelphia [Weather Bureau].

Greatest daily range, 49° at Drifton.

PRECIPITATION.

The average precipitation for the State, for the month, 3·76 inches, is 0·48 inches more than the average [3·28] for the past seven years.

Only a few stations had snowfall in measurable quantities.

General rains occurred on the 1st, 2d, 8th, 9th, 13th, 22d, 27th, 28th, 29th and 30th.

The largest monthly totals of rainfall and melted snow in inches were: Seisholtzville, 7·09; Hamburg, 6·85; East Mauch Chunk, 6·32; *Philadelphia* [Weather Bureau], 6·14; Forks of Neshaminy, 6·04, and Point Pleasant, 5·99.

The least were: Lock Haven, 0·79; Beaver Dam, 1·29; Saegerstown, 1·40; Elwood Junction, 1·66; Towanda, 1·70, and Davis Island Dam, 1·80.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 10; clear days, 10; fair days, 8; cloudy days, 12.

BAROMETER.

The mean pressure for the month, 30·04, is about ·04 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·67 at Philadelphia on the 12th, and the lowest 29·36 at Philadelphia on the 9th.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—Gettysburg, 13th; Le Roy, 25th; Towanda, 25th, 27th, 29th; East Mauch Chunk, 26th; State College, 26th; Grampian, 13th; Uniontown, 13th, 14th; Coopersburg, 1st; White Haven, 27th; Wilkes-Barre, 26th; Easton, 9th; Blooming Grove, 9th; Lewisburg, 27th; Dyberry, 9th, 25th, 27th; Honesdale, 9th, 27th; South Eaton, 9th, 25th, 27th.

Hail.—Gettysburg, 13th; Le Roy, 13th; State College, 13th; Uniontown, 13th; Easton, 2d; Dyberry, 1st.

Snow.—Le Roy, 3d, 15th; Grampian, 2d; Drifton, 2d; Coopersburg, 3d; Smethport, 2d; Blooming Grove, 2d; Dyberry, 2d, 3d; Honesdale, 2d, 3d.

Frost.—Hollidaysburg, 3d, 4th, 11th, 14th, 18th, 19th; Towanda, 18th, 19th, 20th, 24th; Quakertown, 4th, 5th, 18th, 21st, 23d, 24th; Cassandria, 10th, 11th, 14th, 18th, 19th; Emporium, 5th, 11th, 18th, 19th, 20th, 24th; East Mauch Chunk, 5th, 18th, 19th; State College, 18th, 19th, 24th; Saegerstown, 17th, 18th, 19th, 21st, 24th; Uniontown, 3d, 10th, 11th, 19th, 20th, 21st, 24th; Lebanon, 5th, 12th; Williamsport, 18th, 24th; Pottstown, 4th, 5th, 11th, 12th, 18th; South Bethlehem, 3d, 4th, 5th, 11th, 12th, 18th; Easton, 5th, 18th, 19th, 24th; Logania, 18th, 19th; *Philadelphia* [Weather Bureau], 18th; [Centennial Avenue], 11th, 18th, 21st, 24th; Blooming Grove, 18th, 19th, 23d, 24th; Selins Grove, 4th; Somerset, 24th; Wellsboro, 2d, 3d, 4th, 5th, 10th, 11th, 12th, 18th, 19th, 20th, 23d, 24th; Dyberry, 1st, 6th, 11th, 12th, 16th, 17th, 18th, 19th, 20th, 21st, 23d, 24th; South Eaton, 4th, 5th, 6th, 18th, 24th; York, 4th, 19th.

Aurora.—Le Roy, 11th, 19th; Saegerstown, 10th.

Solar Halo.—Le Roy, 12th; *Philadelphia*, Centennial Avenue, 6th, 12th, 17th, 22d; Wellsboro, 12th.

Lunar Halo.—Towanda, 5th; *Philadelphia*, Centennial Avenue, 6th; Wellsboro, 5th.

Parhelias.—Saegerstown, 5th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1895.

County.	Station.	Elevation above Sea Level (feet).	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers
Adams,	Gettysburg,		60.9	94	30	35	17, 22	72.0	49.8	22.2	41	3.16	...	.	13	17	10	4	S	H. F. Buehler.
Allegheny,	Pittsburgh,	820	63.3	93	30	35	22	73.6	53.0	20.6	34	1.97	..	..	10	8	13	10	S	O. D. Stewart, W. B.
Berks,	Hamburg,	380	62.2	96	30	33	17	73.9	50.4	23.5	40	3.23	...	..	7	5	16	10	W	William Shipe.
Berks,	Reading,[2]	280	61.8	...		...	.	...	.	...	...	2.41	...	..	11	..	..	..	...	Franklin Yager.
Blair,	Altoona (30 days),	1,181	65.0	95	31	37	22	75.7	54.3	21.4	41	0.80	...	...	6	..	..	.	...	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	61.8	110	30	25	22	77.7	45.8	31.9	52	2.39	...	...	9	16	7	8	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	59.0	91	31	28	13	70.4	47.7	22.7	34	3.24	...	...	10	15	6	10	SW	G. W. T. Warburton.
Bradford,	Towanda,	754	59.6	93	30	27	17	72.3	47.0	25.3	48	2.56	...	...	9	17	4	10	NW	Hiram E. Bull.
Bucks,	Forks of Neshaminy[1] (27 days),	304	60.7	.	...	...	...	.	..	...	...	2.70	...	...	9	16	..	11	N	J. C. Hilsman.
Bucks,	Quakertown,	536	59.5	95	30	29	17	71.7	47.3	24.4	41	3.60	...	..	8	11	12	8	NW	J. L. Heacock.
Cambria,	Cassandria	2,100	59.5	88	30	31	22	67.3	51.7	15.6	30	4.66	T	...	10	15	8	8	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	61.6	94	31	30	17	75.1	48.1	27.0	42	2.83	T	.	12	14	7	10	S	E. C. Lorentz.
Cameron,	Emporium,	1,050	60.0	98	30	27	17, 22	74.2	45.8	28.4	46	3.08	T	..	8	16	8	7	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	60.8	97	30	28	17	74.2	47.3	26.9	47	2.98	...	..	11	19	7	5	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	59.3	93	30	31	13	69.2	49.4	19.8	30	2.21	...	..	10	9	12	10	S	Prof. Wm. Frear.
Chester,	West Chester,	455	61.4	92	30, 31	38	17, 22	70.9	51.9	19.0	30	3.30	.	...	11	16	4	11	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	61.4	95	31	30	17	73.3	49.4	23.9	40	3.65	...	...	8	13	14	4	S	W. T. Gordon.
Chester	Kennett Square,	275	61.2	94	31	34	17	72.9	49.5	23.4	37	3.30	...	...	12	14	8	9	NW	B. P. Kirk.
Chester,	Phœnixville,‡	190	...	...	...	35	17, 20	...	...	..	...	3.44	...	...	9	11	8	12	SW	T. Knowles Perot.
Chester,	Westtown (30 days),	350	59.9	92	31	34	17	69.9	49.9	20.0	35	3.34	...	...	8	7	16	7	W	John D. Carter.
Clearfield,	Grampian,†	1,450	59.6	94	31	26	13	72.0	47.1	24.9	38	2.38	...	..	10	7	15	9	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	63.2	102	30	30	22	...	...	...	...	2.35	...	..	9	20	6	5	W	Prof. J. A. Robb.
Crawford,	Saegerstown,	1,200	58.7	94	5	24	22	75.2	42.2	33.0	48	3.60	T	..	8	10	10	11	NW	J. G. Apple.
Cumberland,	Carlisle,	480	61.9	100	30	32	17	73.0	50.8	22.2	39	2.34	..	...	10	16	9	6	S	J. E. Pague.
Dauphin,	Harrisburg,	480	62.0	95	30	37	17	71.0	52.0	19.0	35	1.98	...	...	11	21	3	7	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College‡,	361	...	...	...	...	...	...	...	...	...	2.04	...	..	5	..	..	..	..	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	58.0	89	5	26	12	...	...	...	...	..	...	..	.	..	..	..	W	C. F. Sweet.
Erie,	Erie,	1,400	59.0	85	31	32	13	67.0	51.0	16.0	36	2.58	...	..	9	12	13	6	SW	P. Wood, W. B.
Fayette,	Uniontown (29 days),	681	59.2	90	5	29	22	70.7	47.7	23.0	36	2.07	...	..	7	11	16	2	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	60.0	96	30	30	17	72.4	47.6	24.8	42	2.39	...	..	11	8	9	14	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	61.3	98	30	25	14	76.5	46.1	30.4	48	3.01	...	...	8	2	23	6	SE	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	61.2	93	30, 31	36	22	71.8	50.6	21.2	33	3.01	..	...	11	16	8	7	W	A. V. Heister.
Lebanon,	Lebanon,	458	61.0	96	30	32	17	72.6	49.3	23.3	40	1.85	...	...	11	10	12	9	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	60.7	89	30, 31	35	17	70.5	50.9	19.6	32	3.08	...	...	11	13	13	5	SE	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	57.8	93	31	29	17, 21	71.2	44.5	26.7	50	2.03	...		6	7	12	7	N	J. R. Wagner.
Luzerne,	White Haven,		57.6	91	30, 31	26	17	70.4	44.7	25.7	43	2.75	...		5	9	17	5	S	C. M. Driggs.
Luzerne,	Wilkes-Barre,	575	62.4	97	30	30	17, 21	77.8	47.0	30.8	52	4.16	...		7	15	6	10	W	A. W. Betterly.
Lycoming,	Williamsport,		61.5	96	30	33	17, 22	72.1	50.9	21.2	42	3.37	...		9	18	8	5	W	G. D. Snyder, C. E.
McKean,	Smethport,	1,500	56.9	94	30	22	17	71.8	42.0	29.8	46	2.12	...	...	10	10	14	7	SW	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	58.6	94	30	25	21	72.2	45.0	27.2	40	2.75	...	...	7	21	2	8	..	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	63.6	97	31	36	17	74.5	52.6	21.9	36	3.89	...	...	6	14	13	4	S	Charles Moore, D.D.S.
Northampton,	South Bethlehem,	339	62.6	97	30	36	17	74.8	50.5	24.3	39	...	...	...	...	13	9	9	SW	T. Merriman.
Northampton,	Easton— Lafayette College,	325	61.4	93	30, 31	33	17	72.7	50.1	22.6	38	2.58	...	...	8	17	6	8	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	63.2	101	30, 31	31	17	75.2	51.2	24.0	46	2.06	...	...	11	13	9	9	SE	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	62.4	94	30	40	13	71.5	53.3	18.2	29	1.72	...	...	9	8	17	6	NW	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	63.0	96	31	40	2, 13	73.0	52.9	20.1	31	2.03	...	...	8	8	17	6	NW	John Comly.
Pike,	Blooming Grove,*[1]	...	60.0	94	30	36	13	..	...	...	...	2.74	...	...	8	5	21	5	S	John Grathwohl.
Potter,	Shingle House,	1,475	56.6	93	30	23	16, 17	71.6	41.7	29.9	48	2.65	...	...	8	18	3	10	NW	H. L. Pearsall.
Snyder,	Selins Grove,	455	61.2	96	31	29	17	75.9	46.5	29.4	45	3.26	...	...	10	..	22	9	SW	J. M. Boyer.
Somerset,	Somerset (30 days),	2,250	57.2	92	30	25	17	71.5	42.8	28.7	40	1.88	...	...	3	3	19	8	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	55.8	92	30	24	17	.	...	...	...	6.46	...	...	13	13	3	15	S	H. D. Deming.
Union,	Lewisburg	450	61.2	99	30	30	17	74.7	47.7	27.0	46	3.66	...	...	9	12	10	9	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	56.8	90	30, 31	24	17	71.1	42.4	28.7	51	2.52	...	...	7	14	10	7	W	Theodore Day.
Wayne,	Honesdale,	1,000	58.6	91	30	28	17	70.3	46.8	23.5	40	2.89	...	...	11	16	9	6	NW	Andrew Thompson.
Wayne,	(Salem Corners) Hamlinton,	1,600	59.8	96	31	30	13, 22	70.5	49.0	21.5	37	2.87	T	..	14	9	9	13	W	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	63.6	92	31	37	13	72.5	54.7	17.8	41	1.34	...	...	6	..	..	..	...	Murray Forbes.
Wyoming,	South Eaton,	660	59.9	90	30, 31	30	22	71.7	48.1	23.6	42	3.40	...	...	7	17	3	11	NW	B. M. Hall.
York,	York,	385	61.4	95	30	34	17, 22	72.7	50.1	22.6	35	2.73	.	..	13	15	11	5	W	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4 [2] Mean temperature 8 + 8 ÷ 2.
† No records. ‡ Records incomplete.

2	3	4	5	6
·07	·03	. .	. .	. .
·07	·03	. .	. .	. .
·08	. .	. .	. .	. .
·09	·04	. .	. .	. .
·45	·23	·02	. .	. .
·07	·05	. .	. .	. .
·30	·15	. .	. .	. .
·08	. .	. .	·01	. .
·10	·14	. .	. .	. .
·45	·30	. .	. .	. .
. .	. .	. .	. .	. .
·12	·15	. .	. .	. .
. .	·08	. .	. .	. .
·07	·14	. .	. .	. .
·08	·06	. .	. .	. .
·09	. .	. .	. .	. .
·15	. .	. .	. .	. .
·15	. .	. .	·01	. .
·06	·05	. .	. .	. .
·01	. .	. .	. .	. .
·09	·17	·02	·03	. .
. .	. .	. .	. .	. .
·10	. .	. .	. .	. .
. .	. .	. .	. .	
·18	·32	. .	. .	
·28	. .	. .	. .	. .
·31	·01	. .	. .	. .
·10	·13	. .	. .	. .
·30	. .	. .	. .	. .
. .	. .	. .	. .	·02

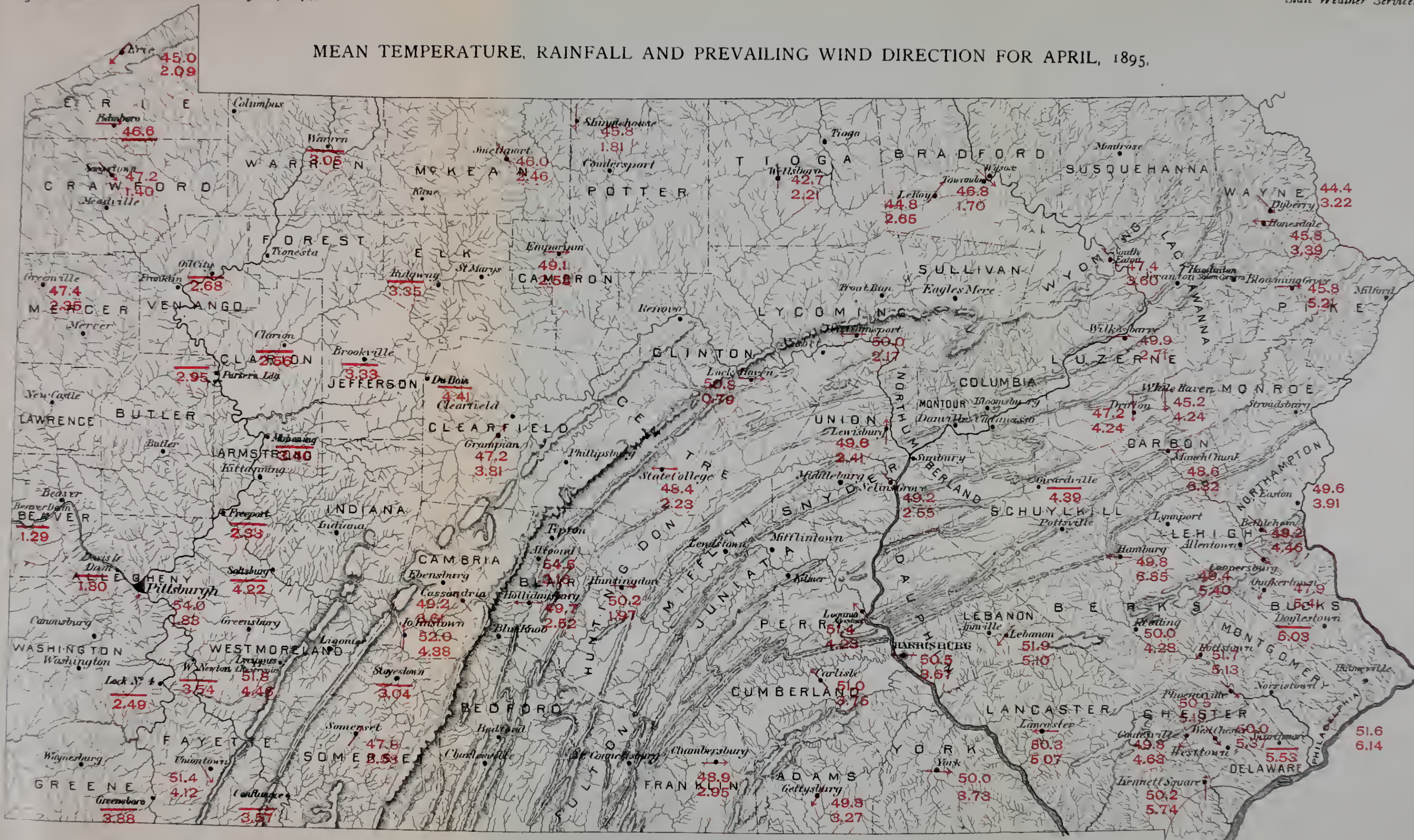
PRECIPITATION DURING MAY, 1895.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Delaware Basin.																																
Bethlehem,									·03			·49		·86							·04						·91					2·33
Blooming Grove,											‡	·68		1·00					·03						·15	‡	·86				·02	2·74
Browers Lock,												·56		·46		·05		·09			·84						1·17					3·17
Coatesville,									·12			·63		·77		·01		·16			·99					·17	·80					3·65
Coopersburg,	·08					·01			·02			·80		·91	·02	·01		·01			·33					·04	·92					3·08
Doylestown,												·34		·28				·03			·07					·05	1·27					2·64
Dyberry,								·32				1·05		·45					·06						·08	·19	·30					2·52
Easton,											‡	·78		·59						‡	·03				‡	‡	·88					2·58
Forks of Neshaminy,	·06					·08						·26		·31		·05		·10			·78					·14	·96					2·70
Frederick,												·57		·70				·04			·57					·07	1·81					3·76
Hamburg,								·51				·52		·94				·06							·06	·61	·53					3·23
Honesdale,								·10	·02			·92	·10	·46	·12				·06						·10	·20	·66				·01	2·89
Kennett Square,	·04					·02	·02		·05			·38		·95		·05		·14			·85	·02				·07	·71					3·30
Lansdale,												·33		·25				·19			·80					·20	·31					2·28
Mauch Chunk,							·05	·05	·03	·01		·93		·87				·02		·02					·03	·23	·74					2·96
Ottsville,						·01						·55		·50				·03			·44					·05	1·15					2·73
Philadelphia, a†	·03					·02						·14		·27				·21			·53	·03				·21	·33					1·72
Philadelphia, b,	·04											·17		·30				·20		‡	·16					·20	·46					2·03
Phoenixville,	·03					·02				·33	·55			·51				·10			·89					·11	·90					3·44
Point Pleasant,												·47		·23							·65						·24	·99				2·78
Pottstown,	·05							·07				·75		1·45							·72						·85					3·89
Quakertown,	·02							·03				·74		·97				·03			·42					·03	1·30					3·60
Reading,	·01							·01	·15			·45		·83				·01	·01		·40				·01	·20	·33					2·41
(Salem Corners) Hamilton,	·22								·27		‡	1·03		·45	·18				‡	·09	·03				‡	·12	·40	·01			·06	2·87
Seisholtzville,	·02							·10					·85	·63					·06		·30					·13	·16					3·15
Smith's Corner,												·57		·28				·04			·56					·10	1·35					2·85
Swarthmore,												·21		·31				·02			·87						·63					2·04
West Chester,	·10					·02	·01		·07			·27		·80		·03		·12			·93					·03	·92					3·30
Westtown,	·05								*			·30		·65		·04		·13			·85					·04	1·28					3·34
White Haven,								·19				1·06		·60						·10							·80					2·75
Susquehanna Basin.																																
Altoona,									·03			·45		·12											·01	·09	·08					0·80
Aqueduct (Logania),								·14	·04		·17	·18		·14				·04	·49	·01					·24	·20	·32					2·06
Carlisle,	·08							·41			‡	·16						·04	·30		·10				·52	·59	·14					2·34
Drifton,					*					·39	·48	*					·21		*	·07						‡	·90			*		2·03
Emporium,							·45	·84			·34			·15					·20						·15	·55	·40					3·08
Gettysburg,	·02							‡	1·50			·15		·11		·04		·06	·15	·01	·41				·06	·27	·38					3·16
Girardville,											·60	·75		·64			·05	·10	·10	·02					·08	·20	·59					3·33
Grampian,							·78	·10	·18		·45			·38					·18	·04					·07	‡	·20					2·38
Harrisburg,†								·26	·32			·08		·10				·06	·38	·02	·10				·12	·23	·31					1·98
Hollidaysburg,								1·13			·33	·32		·20					·05	·02					·09	·12	·13					2·39
Huntingdon,								·85	·07		·85			·23					·31	·02						·40	·28					3·01
Lancaster,								·38			‡	·40	‡	·47			·12		·06		·83				‡	‡	·75					3·01
Lebanon,								·31	·25			·22		·28				·02	·15	·03	·09				·01	·23	·26					1·85
Le Roy,	·02						·05	·73			·60	·50		·25					·48	·05						·02	·54					3·24
Lewisburg,	·08							·47			1·26	·48		·28					·46	·08						·02	·53					3·66
Lock Haven,				·15			·18	·10			·60			·15					·31	·11					·12		·65					2·35
Selins Grove,								·11			·50	·18		·26					·65	·32					·34	·15	·65				·10	3·26
South Easton,								·16			·51	1·33		·44					·25	·05						·66						3·40
State College,	·13							·13			·48	·19		·19					·26	·01					·09	·09	·43					2·21
Towanda,							·03	·47			·40	·62		·25					·34	·03					·03		·39					2·56
Wellsboro,							1·74	·20			·05	·35		1·12	·35	·10			·50	·10	·20				·08	‡	1·67					6·46
Wilkes-Barre								·70			‡	1·95		·35						·15							·86				·15	4·16
Williamsport							1·07	·29			·65			·43					·34	·04					·07		·42				·06	3·37
York,	·02							·95				·15		·10	·05	·02		·04	·33	·03	·49				·07	·30	·18					2·73

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Ohio Basin.																																
Beaver Dam,								·19	·05			·19		·14	·06					·14							·42					1·29
Brookville,								·31	·20			·22		·43						·17							·38					1·77
Cassandria,							·41	·04	·07		1·03			2·55					·10	·06					·08	·14	·28					4·76
Clarion,								·51	·32			·26		·40	·05					·25							·47	·02				2·28
Confluence,								·54	·04		·01	·06		·30	·18	·05				·13	·25	·05			·01	·04	·27					1·54
Davis Island Dam,								·56	·01			·50		·37	·03					·32							·45					2·24
DuBois,								·66	·46			·21		·34	·14					·22							·21					2·24
Elwood Junction,								·38				·67		·16	·07					·24							·25					1·75
Freeport,	·02							·51				·71		·44	·10												·61					2·29
Greensboro,							·05		·02			·42		·33	·05					·05	·10						·53					1·25
Greenville,							·28	·18			1·15			·28						·33						·35	·16					2·75
(Immel Reservoir) Lycippus,								·15			·16		·37	·12					·10								·44					1·34
Johnstown,							·05	·24	·01		1·38	·16	·01	·56	·08				·03	·03					·04	·24						2·83
Lock No. 4,							·03	·23	·04			·31		·32	·05					·07							·66					1·71
Mahoning,								·36	·63			·75		·58	·07					·16							·33					2·18
Oil City,								2·37	·25			·46		·28	·10				·03	·27							·37	·02			·07	4·22
Parker's Landing,								·66	·16			·44		·37	·08					·29							·31	·02				2·33
Pittsburg,†							·40	·02	·02		·27	·14		·24	·02				·20							·04	·52					1·97
Ridgway,								·09	1·30			·26		·24						·20							·42					2·52
Saegerstown,							·40		·08		1·10	·34		·55					·20	·03			·90									3·60
Saltsburg,	·07							·51	·05	·09		·33		·32	·12					·15							·46					2·10
Shingle House,							·25	·95			·25			·05					·35	·10				·05		·55						2·55
Smethport,					·10		·05	·65			·12	·25		·10					·30		·05					·30	·20					2·12
Somerset,							·65				1·10			·13																		1·88
Stoyestown,								·15	·02	·02	·70		·28	·09						·13	·15				·04	·05	·07					1·70
Uniontown,						·48	·33			·08	·14			·36					·08								·60					2·07
Warren,						·01		·35	·38			·30		·34	·07					·38	·05					·01	·43	·04				2·36
West Newton,							·20	·36				·45		·35	·05					·10							·55					2·11
Potomac Basin.																																
Chambersburg,								·53	·26		·37	·10		·10					·36	·02	·17				·14	·17	·17					2·39
Lake Basin.																																
Erie,†							·30	·02			·70	·02		·56	·05				·32							·58	·04					2·58

† U. S. Weather Bureau Stations. * Missing. ‡ Amount included in measurement following.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR APRIL, 1895.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR MAY, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1895.

GENERAL REVIEW.

The average temperature for May, 1895, 60°·6, is 1°·4 above the average [59°·2] for the past seven years.

The highest recorded temperatures occurred on the 30th and 31st, and were as follows: Hollidaysburg, 110°; Lock Haven, 102°; Logania, 101°; and Carlisle, 100°.

The lowest were on the 17th: Smethport, 22°; Shingle House, 23°; Saegerstown, 24°; Wellsboro, 24°; and Dyberry, 24°.

High temperatures prevailed until the 11th, causing rapid growth to vegetation. On the night of the 12th–13th a severe frost occurred, which killed the greater portion of the grape crop and badly injured other fruits. This was followed on the 17th by another damaging frost and freeze, which added additional injury to fruit, corn and early vegetables. Damaging frosts occurred again on the 21st, 22d and 23d. Unusually high temperatures occurred during the balance of the month.

From January 1, 1895, to May 31, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 295°; at Erie, 327°, and at Pittsburgh, 373°.

For the same period the excess in precipitation, in inches, at Philadelphia, was 0·80; and deficiency at Erie 4·89, and at Pittsburgh, 4·49.

TEMPERATURE.

	Mean Temperature.	Mean Precipitation, Inches.
May, 1888	57°·6	4·24
1889	62°·0	5·91
1890	58°·8	6·71
1891	57°·5	2·12
1892	59°·5	5·70
1893	58°·0	5·54
1894	60°·8	8·88
1895	60°·6	2·68

The means of the daily maximum and minimum temperatures, 72°·5 and 48°·6, respectively, give a monthly mean of 60°·6, which is 0°·2 below the corresponding month of 1894.

The average daily range was 23°·9.

Highest monthly mean, 63°·6 at Immel Reservoir (Lycippus) and Pottstown.

Lowest monthly mean, 56°·6 at Shingle House.

Highest temperature recorded during the month, 110° on the 30th at Hollidaysburg.

Lowest temperature, 22° on the 17th at Smethport.

Greatest local monthly range, 85° at Hollidaysburg.

Least local monthly range, 53° at Erie.

Greatest daily range, 52° at Wilkes-Barre.

PRECIPITATION.

The average precipitation for the State, for the month, 2·68 inches, is 2·90 inches less than the average [5·58] for the past seven years.

The rainfall was generally well distributed and timely.

The largest monthly totals of rainfall in inches were: Wellsboro, 6·46; Cassandria, 4·66; Oil City, 4·22; Wilkes-Barre, 4·16; Pottstown, 3·89; and Frederick, 3·76.

The least were: Altoona, 0·80; Beaver Dam, 1·19; Immel Reservoir (Lycippus), 1·34; Greensboro, 1·55; Stoyestown, 1.70; and Brookville, 1·71.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 9; clear days, 13; fair days, 10; cloudy days, 8.

BAROMETER.

The mean pressure for the month, 30·07, is about ·07 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·36 at Philadelphia on the 1st, and the lowest 29·61 at Harrisburg on the 11th and Erie on the 26th.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—Hollidaysburg, 7th, 8th, 11th, 26th; Le Roy, 7th, 8th, 11th; Towanda, 7th, 8th, 11th; Quakertown, 27th; Cassandria, 7th, 26th; Johnstown, 7th, 8th, 11th; Emporium, 7th, 8th, 26th; East Mauch Chunk, 8th; State College, 7th, 11th, 19th; Coatesville, 27th; Kennett Square, 27th; Westtown, 27th; Lock Haven, 4th, 7th, 8th, 11th, 27th; Saegerstown, 6th, 7th, 11th; Harrisburg, 8th, 11th; Uniontown, 6th, 7th; Huntingdon, 5th, 9th, 10th; Lebanon, 8th, 31st; Coopersburg, 11th, 27th; White Haven, 8th, 11th; Wilkes-Barre, 31st; Williamsport, 7th, 8th, 11th, 31st; Easton, 31st; Aqueduct, Logania, 8th, 11th; *Philadelphia* [Weather Bureau], 27th; [Centennial Avenue], 27th; Blooming Grove, 8th, 11th; Somerset, 7th, 11th; Lewisburg, 8th, 11th; Dyberry, 8th, 11th, 31st; Honesdale, 8th, 25th, 31st; Salem Corners (Hamlinton), 8th, 11th; South Eaton, 8th, 11th.

Hail.—Lock Haven, 4th; Williamsport, 12th.

Frost.—Gettysburg, 13th, 17th; Pittsburgh, 13th, 17th, 20th, 21st, 22d; Hollidaysburg, 13th, 17th, 20th, 22d; Le Roy, 13th, 16th, 17th, 20th, 21st, 22d; Towanda, 16th, 17th, 22d; Forks of Neshaminy, 17th; Quakertown, 16th, 17th, 22d, 23d; Cassandria, 14th, 15th, 17th, 18th, 20th, 22d; Johnstown, 13th, 15th, 17th, 22d, 23d; Emporium, 13th, 16th, 17th, 20th, 21st, 22d, 23d; East Mauch Chunk, 17th, 22d; State College, 13th, 17th, 22d; Coatesville, 17th, 22d; Kennett Square, 15th, 17th; Phœnixville, 13th, 15th, 17th; Westtown, 17th; Lock Haven, 13th, 17th; Saegerstown, 12th, 13th, 14th, 16th, 17th, 18th, 21st, 22d, 23d; Carlisle, 17th; Harrisburg, 17th, 22d; Edinboro, 12th, 21st; Uniontown, 13th, 17th, 22d, 23d, 28th; Chambersburg, 22d; Huntingdon, 17th, 22d; Lebanon, 17th, 22d; Coopersburg, 17th; Drifton, 21st; White Haven, 16th, 17th, 22d, 23d; Wilkes-Barre, 17th; Williamsport, 17th, 22d; Greenville, 13th, 17th, 18th, 21st; Pottstown, 17th; South Bethlehem, 17th; Easton, 17th; Aqueduct, Logania, 2d, 15th, 16th, 17th, 22d, 23d; *Philadelphia* [Weather Bureau], 17th; [Centennial Avenue], 17th; Blooming Grove, 16th, 17th; Shingle House, 13th, 16th, 17th, 20th, 21st, 23d; Selins Grove, 13th, 17th, 21st; Somerset, 10th, 13th, 17th, 18th, 22d; Wellsboro, 13th, 16th, 17th, 18th, 20th, 22d; Lewisburg, 17th, 20th, 22d; Dyberry, 2d, 3d, 13th, 16th, 17th, 20th, 21st, 22d, 23d, 29th; Honesdale, 13th, 14th, 16th, 17th, 22d, 23d; Salem Corners (Hamlinton), 13th, 14th, 15th, 16th, 17th, 18th, 22d; South Eaton, 16th, 22d, 23d; York, 17th.

Sleet.—Le Roy, 12th; Salem Corners (Hamlinton), 12th.

Coronæ.—Towanda, 4th, 5th, 30th.

Solar Halo.—Le Roy, 16th, 17th; Towanda, 15th, 18th; South Bethlehem, 17th; *Philadelphia*, [Weather Bureau], 17th; [Centennial Avenue], 2d, 11th, 17th, 24th; Wellsboro, 17th.

Lunar Halo.—Towanda, 3d; *Philadelphia*, [Weather Bureau], 7th.

Parhelias.—Le Roy, 3d.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1895.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1895.

County	Station.	Elevation above Sea Level (feet).	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers
Adams,	Gettysburg,		60·9	94	30	35	17, 22	72·0	49·8	22·2	41	3·16	...		13	17	10	4	S	H. F. Buehler.
Allegheny,	Pittsburgh,	820	63·3	93	30	35	22	73·6	53·0	20·6	34	1·97	...	..	10	8	13	10	S	O. D. Stewart, W. B.
Berks,	Hamburg,	380	62·2	96	30	33	17	73·9	50·4	23·5	40	3·23	...	..	7	5	16	10	W	William Shipe.
Berks,	Reading,[2]	280	61·8	...		...		...	...	...	...	2·41	...	..	11	...	...	...	...	Franklin Yager.
Blair,	Altoona (30 days),	1,181	65·0	95	31	37	22	75·7	54·3	21·4	41	0·80	...	...	6	...	...	...	...	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	61·8	110	30	25	22	77·7	45·8	31·9	52	2·39	...	...	9	16	7	8	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	59·0	91	31	28	13	70·4	47·7	22·7	34	3·24	...	...	10	15	6	10	SW	G. W. T. Warburton.
Bradford,	Towanda,	754	59·6	93	30	27	17	72·3	47·0	25·3	48	2·56	...	...	9	17	4	10	NW	Hiram E. Bull.
Bucks,	Forks of Neshaminy[1] (27 days),	304	60·7	...	...	...	...		..	...	...	2·70	...	...	9	16	..	11	N	J. C. Hilsman.
Bucks,	Quakertown,	536	59·5	95	30	29	17	71·7	47·3	24·4	41	3·60	...	...	8	11	12	8	NW	J. L. Heacock.
Cambria,	Cassandria	2,100	59·5	88	30	31	22	67·3	51·7	15·6	30	4·66	T	...	10	15	8	8	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	61·6	94	31	30	17	75·1	48·1	27·0	42	2·83	T	.	12	14	7	10	S	E. C. Loreotz.
Cameron,	Emporium,	1,050	60·0	98	30	27	17, 22	74·2	45·8	28·4	46	3·08	T	..	8	16	8	7	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	60·8	97	30	28	17	74·2	47·3	26·9	47	2·98	...	...	11	19	7	5	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	59·3	93	30	31	13	69·2	49·4	19·8	30	2·21	...	...	10	9	12	10	S	Prof. Wm. Frear.
Chester,	West Chester,	455	61·4	92	30, 31	38	17, 22	70·9	51·9	19·0	30	3·30	...	...	11	16	4	11	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	61·4	95	31	30	17	73·3	49·4	23·9	40	3·65	...	...	8	13	14	4	S	W. T. Gordon.
Chester	Kennett Square,	275	61·2	94	31	34	17	72·9	49·5	23·4	37	3·30		...	12	14	8	9	NW	B. P. Kirk.
Chester,	Phœnixville,‡	190	...	...	...	35	17, 20	...	...	...	...	3·44	...	...	9	11	8	12	SW	T. Knowles Perot.
Chester,	Westtown (30 days),	350	59·9	92	31	34	17	69·9	49·9	20·0	35	3·34	...	...	8	7	16	7	W	John D. Carter.
Clearfield,	Grampian,†	1,450	59·6	94	31	26	13	72·0	47·1	24·9	38	2·38	...	..	10	7	15	9	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	63·2	102	30	30	22	...	...	...	...	2·35	...	..	9	20	6	5	W	Prof. J. A. Robb.
Crawford,	Saegerstown,	1,200	58·7	94	5	24	22	75·2	42·2	33·0	48	3·60	T	..	8	10	10	11	NW	J. G. Apple.
Cumberland,	Carlisle,	480	61·9	100	30	32	17	73·0	50·8	22·2	39	2·34	...	...	10	16	9	6	S	J. E. Pague.
Dauphin,	Harrisburg,	480	62·0	95	30	37	17	71·0	52·0	19·0	35	1·98	...	...	11	21	3	7	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College‡,	361	...	...	...	...	...	...	...	...	...	2·04	...	..	5	..	.	..	..	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	58·0	89	5	26	12	...	...				...						W	C. F. Sweet.
Erie,	Erie,	1,400	59·0	85	31	32	13	67·0	51·0	16·0	36	2·58	...	..	9	12	13	6	SW	P. Wood, W. B.
Fayette,	Uniontown (29 days),	681	59·2	90	5	29	22	70·7	47·7	23·0	36	2·07	...	..	7	11	16	2	SW	Wm. Huot.
Franklin,	Chambersburg,	1,000	60·0	96	30	30	17	72·4	47·6	24·8	42	2·39	...	..	11	8	9	14	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	61·3	98	30	25	14	76·5	46·1	30·4	48	3·01	...	...	8	2	23	6	SE	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	61·2	93	30, 31	36	22	71·8	50·6	21·2	33	3·01	..	...	11	16	8	7	W	A. V. Heister.
Lebanon,	Lebanon,	458	61·0	96	30	32	17	72·6	49·3	23·3	40	1·85	...	...	11	10	12	9	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	60·7	89	30, 31	35	17	70·5	50·9	19·6	32	3·08	...	...	11	13	13	5	SE	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	57·8	93	31	29	17, 21	71·2	44·5	26·7	50	2·03	...	...	6	7	12	7	N	J. R. Wagner.
Luzerne,	White Haven,		57·6	91	30, 31	26	17	70·4	44·7	25·7	43	2·75	...		5	9	17	5	S	C. M. Driggs.
Luzerne,	Wilkes-Barre,	575	62·4	97	30	30	17, 21	77·8	47·0	30·8	52	4·16	...	...	7	15	6	10	W	A. W. Betterly.
Lycoming,	Williamsport,		61·5	96	30	33	17, 22	72·1	50·9	21·2	42	3·37	...	...	9	18	8	5	W	G. D. Snyder, C. E.
McKean,	Smethport,	1,500	56·9	94	30	22	17	71·8	42·0	29·8	46	2·12	...	...	10	10	14	7	SW	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	58·6	94	30	25	21	72·2	45·0	27·2	40	2·75	...	...	7	21	2	8	...	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	63·6	97	31	36	17	74·5	52·6	21·9	36	3·89	...	...	6	14	13	4	S	Charles Moore, D.D.S.
Northampton,	South Bethlehem,	339	62·6	97	30	36	17	74·8	50·5	24·3	39	...	...	...	...	13	9	9	SW	T. Merriman.
Northampton,	Easton— Lafayette College,	325	61·4	93	30, 31	33	17	72·7	50·1	22·6	38	2·58	...	...	8	17	6	8	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	63·2	101	30, 31	31	17	75·2	51·2	24·0	46	2·06	...	...	11	13	9	9	SE	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	62·4	94	30	40	13	71·5	53·3	18·2	29	1·72	...	...	9	8	17	6	NW	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	63·0	96	31	40	2, 13	73·0	52·9	20·1	31	2·03	...	...	8	8	17	6	NW	John Comly.
Pike,	Blooming Grove,*[1]	...	60·0	94	30	36	13	..	...	...	...	2·74	...	..	8	5	21	5	S	John Grathwohl.
Potter,	Shingle House,	1,475	56·6	93	30	23	16, 17	71·6	41·7	29·9	48	2·65	...	..	8	18	3	10	NW	H. L. Pearsall.
Snyder,	Selins Grove,	455	61·2	96	31	29	17	75·9	46·5	29·4	45	3·26	...	...	10	..	22	9	SW	J. M. Boyer.
Somerset,	Somerset (30 days),	2,250	57·2	92	30	25	17	71·5	42·8	28·7	40	1·88	...	...	3	3	19	8	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	55·8	92	30	24	17	.	...	...	...	6·46	...	..	13	13	3	15	S	H. D. Deming.
Union,	Lewisburg	450	61·2	99	30	30	17	74·7	47·7	27·0	46	3·66	...	..	9	12	10	9	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	56·8	90	30, 31	24	17	71·1	42·4	28·7	51	2·52	...	..	7	14	10	7	W	Theodore Day.
Wayne,	Honesdale,	1,000	58·6	91	30	28	17	70·3	46·8	23·5	40	2·89	...	...	11	16	9	6	NW	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	59·8	96	31	30	13, 22	70·5	49·0	21·5	37	2·87	T	..	14	9	9	13	W	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	63·6	92	31	37	13	72·5	54·7	17·8	41	1·34	...	..	6	..	..	..	...	Murray Forbes.
Wyoming,	South Eaton,	660	59·9	90	30, 31	30	22	71·7	48·1	23·6	42	3·40	...	..	7	17	3	11	NW	B. M. Hall.
York,	York,	385	61·4	95	30	34	17, 22	72·7	50·1	22·6	35	2·73		..	13	15	11	5	W	Mrs. L. H. Grenewald.

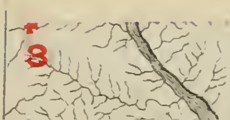
Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean temperature 8 + 8 ÷ 2.
† No records. ‡ Records incomplete.

1895.

1

·02

·07



PRECIPITATION DURING MAY, 1895.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin																																
Bethlehem,									·03			·49		·86							·04						·91					2·33
Blooming Grove,											‡	·68		1·00					·03						·15	‡	·86				·02	2·74
Browers Lock,												·56		·46		·05		·09			·84						1·17					3·17
Coatesville,									·12			·63		·77		·01		·16			·99					·17	·80					3·65
Coopersburg,	·02					·01			·02			·80		·90	·02	·01		·01			·33					·04	·92					3·08
Doylestown,												·34		·28				·03			·67					·05	1·27					2·64
Dyberry,								·39				1·05		·45					·06						·08	·19	·30					2·52
Easton,											‡	·78		·89						‡	·03				‡	‡	·88					2·58
Forks of Neshaminy,	·06					·02						·28		·31		·05		·10			·78					·14	·96					2·70
Frederick,												·57		·70				·04			·57					·07	1·81					3·76
Hamburg,								·51				·52		·94				·06							·06	·61	·53					3·23
Honesdale,								·20	·02			·92	·10	·46	·12				·08						·10	·20	·68				·01	2·89
Kennett Square,	·04					·02	·02		·05			·38		·95		·05		·14			·85	·02				·07	·71					3·30
Lansdale,												·53		·25				·19			·80					·20	·31					2·28
Mauch Chunk,							·05	·05	·03	·01		·93		·87				·02		·02					·03	·23	·74					2·98
Ottsville,						·01						·55		·50				·03			·44					·05	1·15					2·73
Philadelphia, a†	·03					·02						·14		·22				·21			·53	·03				·21	·33					1·72
Philadelphia, b,	·04											·17		·30				·20		‡	·66					·20	·46					2·03
Phœnixville,	·03					·02				·33	·55			·51				·10			·89					·11	·90					3·44
Point Pleasant,												·47		·23							·85						·24	·99				2·78
Pottstown,	·05							·07				·75		1·45							·74						·85					3·89
Quakertown,	·02							·03				·74		·97				·03			·42					·03	1·36					3·60
Reading,	·01							·01	·15			·45		·83				·01	·01		·40				·01	·20	·33					2·41
(Salem Corners) Hamlinton,	·22								·27		‡	1·03		·45	·18				‡	·09	·03				‡	·12	·40	·02			·06	2·87
Seisholtzville,	·02							·10					·85	·83					·06		·30					·13	·86					3·15
Smith's Corner,												·52		·28				·04			·56					·10	1·35					2·85
Swarthmore,												·21		·31				·02			·87						·63					2·04
West Chester,	·10					·02	·01		·07			·27		·80		·03		·12			·93					·03	·92					3·30
Westtown,	·05								*			·30		·65		·04		·13			·85					·04	1·28					3·34
White Haven,								·19				1·06		·60						·10							·80					2·75
Susquehanna Basin.																																
Altoona,									·03			·45		·12											·03	·09	·08					0·80
(Aqueduct) Logania,								·14	·04		·17	·18		·14				·04	·49	·01					·24	·20	·32					2·06
Carlisle,	·08							·41			‡	·16						·04	·30		·10				·52	·59	·14					2·34
Drifton,					*					·39	·46	*					·21		*	·07						‡	·90			*		2·03
Emporium,							·45	·84			·34			·15					·20						·15	·55	·40					3·08
Gettysburg,	·02							‡	1·50			·15		·11		·04		·06	·15	·01	·41				·06	·27	·38					3·16
Girardville,											·80	·75		·64			·05	·10	·10	·02					·08	·20	·59					3·33
Gramplan,							·78	·10	·18		·45			·38					·18	·04					·07	‡	·20					2·38
Harrisburg,†								·26	·32			·08		·10				·06	·38	·02	·10				·12	·23	·31					1·98
Hollidaysburg,								1·13			·33	·32		·20					·05	·02					·09	·12	·13					2·39
Huntingdon,								·85	·07		·85			·23					·31	·02						·40	·28					3·01
Lancaster,								·38			‡	·40	‡	·47			·12		·06		·83				‡	‡	·75					3·01
Lebanon,								·31	·25			·22		·28				·02	·15	·03	·09				·01	·23	·26					1·85
Le Roy,	·02						·05	·73			·60	·50		·25					·48	·05						·02	·54					3·24
Lewisburg,	·08							·47			1·26	·48		·28					·46	·08						·02	·53					3·66
Lock Haven,				·15			·16	·10			·60			·15					·31	·11					·12		·65					2·35
Selins Grove,								·11			·50	·18		·26					·65	·32					·34	·15	·65				·10	3·26
South Eaton,								·16			·51	1·33		·44					·25	·05						·66						3·40
State College,	·13							·13			·48	·39		·19					·26	·01					·09	·09	·43					2·21
Towanda,							·03	·47			·40	·62		·25					·34	·03					·03		·39					2·56
Wellsboro,							1·74	20			·05	·35		1·12	·35	·10			·50	·10	·20				·08	‡	1·67					6·46
Wilkes-Barre,								·70			‡	1·95		·35						·15							·86				·15	4·16
Williamsport,							1·07	·29			·65			·43					·34	·04					·07		·42				·06	3·37
York,	·02							·95				·15		·10	·05	·02		·04	·33	·03	·49				·07	·30	·18					2·73

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,								·19	·05			·19		·14	·06					·14							·42					1·19
Brookville,								·31	·20			·22		·45						·17							·38					1·71
Cassandria,							·41	·04	·07		1·03			2·55					·10	·06					·08	·14	·18					4·66
Clarion,								·51	·32			·26		·40	·05					·25							·47	·02				2·28
Confluence,								·54	·04		·01	·06		·30	·18	·05				·13	·26	·05			·01	·04	·27					1·94
Davis Island Dam,								·56	·01			·50		·37	·03					·32							·45					2·24
DuBois,								·66	·46			·21		34	·14					·22							·31					2·24
Elwood Junction,								·38				·67		·16	·07					·24							·23					1·75
Freeport,	·02							·51				·71		·44	·10												·61					2·39
Greensboro,							·05		·02			·42		·33	·05					·05	·10						·53					1·55
Greenville,							·28	·18			1·15			·28						·33						·35	·18					2·75
(Immel Reservoir) Lycippus,								·15			·16		·37	·12					·10								·44					1·34
Johnstown,							·05	·24	·01		1 38	·16	·01	56	·08				·03	·03					·04	·24						2·83
Lock No. 4,							·03	·23	04			·31		·32	·05					·07							·66					1·71
Mahoning,								·36	·03			·75		·58	·07					·16							·33					2·28
Oil City,								2·37	·25			·46		·28	·10				·03	·27							·37	·02			·07	4·22
Parker's Landing,								·66	·16			·44		·37	·08					·29							·31	·02				2·33
Pittsburg,†							·40	·02	·02		27	·14		·34	·02				·20							·04	·52					1·97
Ridgway,								·09	1·30			·26		·24						·20							·42					2·51
Saegerstown,							·40		·08		1·10	·34		·55					·20	·03			·90									3·60
Saltsburg,	·07							·51	·05	·09		·33		·32	·12					·15							·46					2·10
Shingle House,							·25	·95			·25			·05					·35	·20				·05		·55						2·65
Smethport,					·10		·05	·65			·12	·25		·10					·30		·05					·30	·20					2·12
Somerset,							·65				1·10			·13																		1·88
Stoyestown,								·15	·02	·02	·70		·28	·09						·13	·15				·04	·05	·07					1·70
Uniontown,						·48	·33			·08	·14			·36					·08								·60					2·07
Warren,						·01		·35	·38			·30		·34	·07					·38	·05					·01	·43	·04				2·36
West Newton,							·20	·38				·45		·35	·05					·10							·58					2·11
Potomac Basin.																																
Chambersburg,								·53	·26		·37	·10		·10					·36	·02	·17				·14	·17	·17					2·39
Lake Basin.																																
Erie,†							·30	·02			·70	·01		·56	·05				·32							·58	·04					2·58

† U. S. Weather Bureau Stations. * Missing. ‡ Amount included in measurement following.

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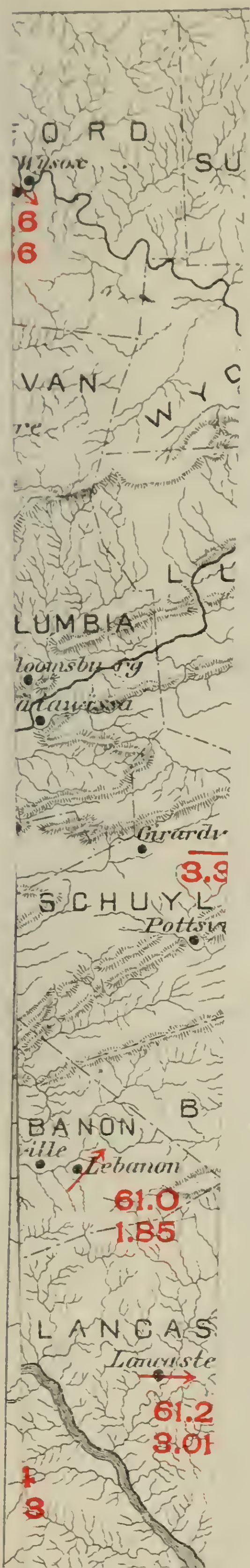

ORD
SU
VAN
LUMBIA
Girardv
3.3
SCHUYL
Potts
BANON
B
Lebanon
61.0
1.85
LANCAS
Lancaste
61.2
3.01

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR MAY, 1895.